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Locoweed Disease of Sheep

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BULLETIN OF THE PHILOSOPHICAL SOCIETY
SCIENTIFIC SECTION
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LOCOWEED DISEASE OF SHEEP*

BY

HARRY T. MARSHALL.

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Synonyms: Loco disease, loco, locoism, crazyweed disease, crazy disease, rattleweed disease.

There is an opinion widely current that the live stock ranging over the Western plains and Rocky Mountain regions are remarkably free from disease. The general prosperity of the ranch owners has served in great measure to divert attention from the losses and failures befalling certain of their number and it has taken many years to bring a realization of the menace presented by diseases to the continued success of stock raisers in the West. That parasitic diseases occur in sections of the West has been shown by Curtice, Stiles, Ransom, and other members of the Bureau of Animal Industry. Recently Hall† has shown by charts the present

* The work described in the following report was conducted by me at the request of the U. S. Department of Agriculture, under the supervision of Prof. V. K. Chesnut of the Office of Poisonous Plant Investigation. In addition to his hearty coöperation in many other ways Prof. Chesnut identified the locoweeds used in the experiment and selected the regions over which the loco feeding experiments were conducted. Dr. Charles Wardell Stiles was kind enough to determine the specific identity of the parasites found in my examinations of the sheep during 1903. Mr. B. H. Ransom of the the Bureau of Animal Industry has made a special study describing a new stomach worm of sheep found in the course of my autopsies (Bureau of Animal Industry, 1911, Bull. 127, pp. 62–66). The authorities of the Montana Agricultural College coöperated very courteously with us and moreover performed a valuable and important work in studying the market value of the sheep which were left over from my experiments. Finally, it is a pleasure to acknowledge, even at this late date, my appreciation of the hospitality, interest and assistance everywhere offered us by the ranchmen of Montana.

† U. S. Bureau of Animal Industry, 27th Report for 1910; pub. 1912, pp. 419–461.

known distribution of the parasitic diseases of sheep, but complete systematic studies of the prevailing parasitic diseases of Western live stock have not been made and knowledge upon this subject is incomplete. With regard to poisonous plants it has been shown in a number of publications from the Bureau of Plant Industry such as those by V. K. Chesnut and by Chesnut and Wilcox that there are several widespread and highly poisonous plants on the Western plains which occasionally cause great losses among stock.

The ranchmen themselves attribute great losses to the poisonous action of the locoweed, and this matter has given rise to much writing. The botanical characteristics and distribution of the various locoweeds were studied by Chesnut and others. After Chesnut's report appeared—in which he also described the general symptoms of the locoed animals—I was engaged by the Bureau of Plant Industry to study locoed animals in Montana for the purpose first, of giving a clear description of the symptoms characteristic of locoweed poisoning, and second, of locating and describing the anatomical changes produced in animals from eating the weed. As the result of my findings it proved necessary to conduct a feeding experiment in order to settle the vexed question as to whether it is possible to obtain uncomplicated cases of genuine locoweed poisoning. Inasmuch as other publications have appeared upon the subject of locoweed poisoning since 1903 and 1904, when my studies were made, I conclude this report with a review of the recent literature and with a discussion of the loco problem, as it confronts us today.

The report falls into several divisions:

A. Information obtained from the ranchmen and from literature.

B. The results of examinations of typical "locoed" sheep as they were met with on the ranches.

C. The description of feeding experiments and the results obtained from them.

D. Discussion of the parasitic diseases encountered.

E. A review of recent publications dealing with loco disease.

F. The present status of the "Loco problem."

A. INFORMATION OBTAINED FROM THE RANCHMEN AND FROM THE LITERATURE.

The spread of loco disease. Inasmuch as Marsh* and Crawford† have published elaborate bibliographies and historical reviews of locoweed disease, only special features will be selected for remark here. It seems probable from such information as can be obtained that loco disease was first observed in Mexico or Texas, and thus received its Spanish name of "loco" or "crazy" disease. It was known in the seventies in California; about the same time in Texas and Colorado; a few years later in Wyoming, and apparently it was first observed in Montana about 1884, when Jacob Severence described "loose-teeth lambs." Its general recognition in Montana dates from about 1890. It seems probable that loco disease spread northward from Mexico, the disease becoming notable in each locality ten, twelve, or fifteen years after the ranges were first occupied by live stock. Apparently a very large part of the live stock of the West is descended from old Mexican stock, the animals having been driven further and further north as fresh ranges were needed.

Definition. The general opinion in the West is that locoweed disease is a definite form of drug poisoning produced by the locoweed in animals which have formed the habit of eating the weed. Most ranchmen believe that the whole plant is poisonous, a few hold that the poison resides in the flowers, a large number consider the roots to be the most dangerous part of the plant. Some believe that one variety of locoweed is more dangerous, others, another.

A small number of ranchmen reject the view that the locoweed is poisonous. Most of these men believe that the craving for the locoweed prevents animals from eating a sufficient quantity of nutritious food, and that the symptoms are those of starvation. Others contend that the locoweed is of itself altogether harmless, and that the symptoms are caused by some worm or other parasite residing in the locoweed. A very small number believe that all cases of "locoweed disease" are in reality examples of other diseases, such as starvation, or parasitic infection.

The locoweed. There is some confusion as to the identity of the locoweed. Many other plants have been called locoweed, and there is no doubt that many cases of poisoning by other plants have been looked upon as cases of locoweed disease. The botanical characteristics of the various locoweeds have been given in Bulletins 20 and 26 of the Depart-

* Bureau of Animal Industry, Bull. 112, 1909.

† Bureau Plant Industry, Bull. 129, 1908.

forced out of business by this scourge, while other ranchmen in the same neighborhood have escaped loss from the disease almost altogether. Accounts indicated in 1903 that the disease was increasing. According to the ranchmen there are the most remarkable variations in the prevalence of the disease from year to year. A region previously free from the disease may suddenly be devastated by it, only to have it subside or disappear again after a year or two. It could not be ascertained that such outbreaks are coincident with a sudden spread of the locoweed. It is claimed by some, however, that the abundance of the weed varies from year to year.

11. Old ranges. The "loco disease" does not make its appearance when a ranch is first occupied. Thus in Montana the disease was first noticed about ten or twelve years after the plains were settled by the rangers. In Eastern Colorado the evidence was similar. The stock rangers explain the delayed appearance of the disease as the result of a steady decrease of available grazing lands, combined with a rapidly increasing overstocking of the ranches, producing a shortage of grass, and the adoption of the locoweed as food by the hungry animals.*

12. Outbreaks. It is rare for isolated cases to occur, although they are met with. Such cases are most often found in horses. As a rule if one animal on the ranch becomes "locoed" a large proportion of all the young animals will develop the disease. As stated above locoweed disease is frequently enzootic throughout an entire region. Whether the infection attacks all animals or only single species could not be determined. The evidence at hand indicates that the "loco" outbreak is confined to one species, for example, sheep.

13. Seasonal variations. In Montana the first cases of "loco" occur a few weeks after the plant becomes green—that is during April and May. These are regarded as chiefly relapses from the year before. Very few cases develop during the summer. The greatest number of new cases appear in the autumn—November and December. Further south (Colorado) the height of the disease is said to be earlier in the spring and later in the autumn.

The ranchmen hold divergent views as to the relation between the incidence of the disease and the season's rainfall, some holding that more

* Within recent years the number of animals grazed on a given tract of land has risen enormously. One ranger in Montana informed me that 40,000 sheep now graze on a tract formerly ranged over by 6000. The fencing in of the ranges, and the settlement of the public lands, have served to curtail the available ranging lands to a fraction of their former extent, so that at the present time a larger number of animals grazes over a smaller tract than formerly, and returns to the same tract at shorter intervals.

"loco disease" is seen during moist seasons, others that a dry season favors the spread of the disease by decreasing the amount of the nutritious grasses.

Symptoms and course of the disease. The onset is described as being usually gradual and insidious, several weeks after the animal first eats the weed. A rapid onset is described at times, and occasionally symptoms appear within a week after exposure. In Eastern Colorado it seems not unusual for a horse to become "locoed" a day or two after beginning to eat the weed. The symptoms are more definite in the horse. A previously well broken horse becomes unmanageable, bucking, rearing and exhibiting various vicious traits, together with a high degree of nervousness. The animal appears to suffer from defective vision and even from hallucinations. It is subject to tremors of excitement. Most characteristic appears to be the tendency of "locoed" horses to balk at objects in front of them. Thus they will balk at a stick or a rope lying in their path, and if forced to cross it, they will clear it with a leap several feet in the air. It is said that a "locoed" horse cannot be led nor ridden, though it may at times be driven, but that when once started the horse will not stop before it is exhausted. The nervous symptoms continue. Very soon the animal begins to lose strength and weight; emaciation finally becomes extreme, the coat is rough and dull, the ears and head droop, the gait becomes weak and unsteady, the eyes sunken and glassy, and the animal very apathetic. Occasionally one side or one limb may be weaker than the rest of the animal. Stiffness of the hind legs is especially common. Schwartzkopf states that the pupils are widely dilated and that there is a decrease of sensibility to mechanical stimulation. Apparently the animal is in almost a constant state of nervous tremor. The disease is usually chronic, lasting from several months up to two or three years. The horse spends its time searching for the locoweed, which it may even dig up by the roots with its hoof. In the last stages the horse may walk blindly into a tree or rock and stand pushing against it until it drops from exhaustion, or it may fall in the water from which it is drinking and drown. In the chronic disease, horses occasionally exhibit acute maniacal attacks from which they may die suddenly with evidences of great pain. Acute attacks, can be brought on by exciting the animal or by making it exercise until it is hot.

Locoweed disease of sheep and cattle is less fully described. The chief symptoms are the habit of eating the locoweed, nervousness, loss of weight and strength ending in great emaciation, with dull glassy eyes, rough coat, and finally death from exhaustion. Stiffness of the muscles of the neck and hind legs is regarded as quite characteristic in sheep.

Morbid anatomy. No characteristic lesion has been found except the

changes described by Marsh (l. c.) and reviewed below in Section E. An increase in the fluid beneath the meninges and in the ventricles of the brain has been described by Stalker and by Schwartzkopf. Scheuchardt states that Schwartzkopf found no bacteria in his cases.

Prognosis. The outlook for locoed animals is usually bad. If the disease is detected in the early stage the animal may be saved if it is fed up on grain, hay, etc., or if sent to a country free from the weed. As a rule the disease is not detected early, and the general attitude of the ranchman is that of non-interference. Even after an apparent cure the animal will relapse if turned out to graze in the former pasturage.

B. EXAMINATIONS OF "LOCOED" SHEEP.

Several hundred "locoed" sheep were seen on various ranches in Montana. No locoed horses could be found. Loco disease of cattle is a rarity in Montana and no cases could be found. Experienced sheep raisers selected a few of the illest and most typically locoed sheep from among the invalids and turned them over to me. Animals selected in this way furnished the materials for the following study.

Six of the illest lambs obtainable were fed for about two weeks on loco-weed (*A. spicatus*), gathered fresh every day. *The animals did not like the food*, and at first ate sparingly of it, but more abundantly after a few days. No change in their condition could be detected as the result of this diet, and no acute symptoms were induced (see cases 8, 9 and 11).

A synopsis of the cases examined follows. The anatomical diagnosis was usually confirmed by the microscopic study of tissues fixed in Zenker's fluid or alcohol, sectioned and stained with hematoxylin and eosin. The central nervous system was not studied microscopically, but the brain, cord and membranes were examined at autopsy.

Histories of sheep studied during September and October of 1903.

ANIMAL No. 1. Sheep, female, about eighteen months old from the Briggs-Ellis Ranch, Big Timber, Montana (Mr. James Vestal), September 24. This sheep was picked out by Mr. Vestal from an invalid band of between fifteen and thirty "locoed" animals, and selected by him as presenting the features of loco most typically and most severely.

When examined, animal was in corral, separated from other sheep; appeared apathetic, not eating nor noticing its surroundings. When alarmed, it ran off at a trot with a stiff gait and stumbling, the legs flying out in an incoördinate manner. The sheep was very weak and tremulous, especially in the hind legs, the tremor worse on movement. There was slight lateral nystagmus. When laid on the ground the animal was hardly able to rise. The hind legs were not able properly to support the

animal. The pupils were only moderately dilated. The animal was greatly emaciated and undersized, and stood with head and ears drooping, hardly making a movement. Observed to remain in one position for one hour and thirty minutes and then moved only upon being disturbed. Every two or three minutes a brief spasm contracted the abdominal muscles, less often the muscles of one of the legs.

The vision of the animal was apparently good. She observed movements 10 or 20 feet away. When the hand was waved around slowly at a distance of 2 feet from the animal, she became greatly alarmed and trembled, and shrank against the wall. Hearing apparently acute. If hands were clapped together, even gently, up to a distance of 20 feet from the animal it quivered at the clap but paid no further attention. Tactile sensation apparently not exaggerated. The end of the nose and skin of the body were not unduly sensitive.

September 26 at 12.30 p.m. animal chloroformed. Autopsy No. 1 performed at once. Upon opening the spinal cord and brain, firm adhesions were found between the dura and the base of the skull along the right side extending from the level of the sella turcica posteriorly nearly to the foramen magnum. Upon removing the dura an abscess was opened into between the dura and the base of the skull containing between 2 and 4 drams of thick, viscid, yellow pus with a faint, unpleasant, rather fishy odor.

The brain was symmetrical, convolutions slightly flattened. The vessels not injected except adjacent to abscess where the surface of the brain was roughened and a small amount of exudate had collected in the pia-arachnoid.

Longitudinal section of the head through the nares and roof of mouth presented no abnormality and did not reveal the starting point of the abscess. Incisor teeth were quite loose, and irregular in size, shape, and position.

Subcutaneous and peritoneal fat almost absent. Muscles of the back and abdomen pale, reddish, and translucent.

Pleural cavities dry; left lung adherent at the apex and at two or three points to the diaphragm, being bound by quite firm, fibrous adhesions. Lung was small; generally crepitant, and of a reddish pink color. The bronchi and vessels were clear. The bronchi and trachea pale and dry. Scattered through the lung were 8 to 12 nodules varying from 2 mm. to 5 cm. in diameter, averaging 1.5 to 2 cm., fluctuating, raised, firmer, slightly tense with a yellow center surrounded by a narrow rim of dark red consolidated lung. These areas were the parts adherent to the diaphragm and apex. On section of such a nodule, in the center was found a core of semi-solid, semi-purulent, cheesy, material about two-thirds the size of the nodule, contained in a smooth-walled, cyst-like cavity surrounded by the red, consolidated rim of lung. No miliary nor conglomerate tubercles were found in the consolidated regions. The lymph glands at the hilum of the lung were not large nor caseous.

The right lung presented the same appearance as left, and contained from 8 to 10 nodules.

Heart. Parietal and visceral pericardial layers were normal. A few cubic centimeters (3 to 5) of clear, amber, fluid were present. The subepicardial fat almost absent. The heart valves were clear and delicate. The cavities appeared normal, the muscle was semi-translucent, reddish brown; the heart weighed 35 grams.

Spleen weighed 100 grams, measured 12 x 8 x 2 cm., surface smooth, consistence soft, color dark red; on section uniform in appearance, not opaque and apparently was normal.

Liver weighed 175 grams. Dimensions 18 x 12 x 3 cm. Surface smooth and glistening. Consistence soft, edge sharp. On section the liver was uniformly dark brown, the lobules not distinct. Over the posterior border of the upper right lobe were a few white pin-point areas of thickening in the capsule. A tapeworm was found in the bile duct and adjacent intestine, and was identified as the "fringed tapeworm," or "liver tapeworm," its technical name being "*Thysanosoma actinioides*."

Left kidney. Capsule stripped readily leaving a smooth, brownish surface with a thick cortex (between 9 and 11 mm.). Glomeruli showed as red points; striae fairly well marked, boundary zone visible. The pyramids and pelvis of kidney appeared normal. Right kidney had the same appearance as left. Combined weight of kidneys 85 grams. The digestive tract presented no abnormality upon opening it except for the presence of tapeworms. The pelvic viscera, uterus, tubes and ovaries were clear except that a soft parasitic cyst was found attached to the right broad ligament.

Microscopic report. Paraffin sections. Stained with hematoxylin and eosin. Heart muscle stained well and appeared clear and normal, both fibrils and striations standing out distinctly. Scattered quite thickly through the heart muscle were deep bluish masses, circular, or oval, from three to fifteen times the size of the heart muscle cell. These were seen to be made up of a colorless, thin capsule in which were tightly packed great numbers of comma-shaped, or crescentic-shaped, deeply blue staining masses. There was apparently no reaction in the muscle outside but here and there one gained the impression that these cysts containing blue chromatin masses were embedded in a heart muscle cell.

Lung. Section through nodule. The cavity was seen to be a dilated bronchiole. The plug had fallen from the center, most of the mucosa had dropped off, and there was left a wall containing abundant loose fibroblastic tissue outside of which were a few compressed lung alveoli, passing rapidly into rather congested lung tissue. A second nodule of lung showed on section a bright pink necrotic structureless center. The mucosa was practically entirely gone or else overgrown by an abundant, loose, fibroblastic tissue which occasionally nearly enclosed a small strand or two of columnar epithelial cells. The new tissue contained, especially near the necrotic border, great numbers of lymphocytes and of eosinophilic cells. Apparently many of these eosinophiles were mononuclear, although the majority were polymorphonuclear. In the region outside of the organized tissue, more or less compressed lung was found with the alveoli partially filled with an exudate composed chiefly of desquamated epithelial cells and polymorphonuclears. Diagnosis—Organizing bronchiectasis and bronchopneumonia. Other nodules from the lung presented much the same appearance. In none of these sections were tubercles found in the consolidated area.

Spleen showed lymphoid hyperplasia and some phagocytic endothelioid cells, but otherwise appeared normal. The liver showed a definite though not very pronounced increase in the cells surrounding the somewhat dilated bile ducts. These cells were in part fibroblasts but chiefly lymphoid cells and a few eosinophilic cells. Kidney capsule not thickened; glomeruli appeared normal; slightly congested. Tubular epithelium slightly cloudy though hardly more so than normally. No increase in the intertubular connective tissue. Lymph gland (from hilum of lung). Capsule not thickened. Germinal centers well marked. A few of them showed lymphatic hyperplasia with large cells near the middle and some evidence of cell divisions in this region. The sinuses toward the center were widely dilated and

contained numerous large desquamated endothelial cells with rather abundant pink cytoplasm. Among them were a number of cells showing the nuclear changes of cell division. Many of these desquamated cells contained what appeared to be hemoglobin. In the cell columns also were found evidences of cell division. The peripheral sinus was not dilated. Diagnosis—Lymphoid hyperplasia.

Diaphragm. Section was characterized by the presence of about a dozen cysts like those found in the myocardium, the cyst being enclosed within a muscle cell, although there was no reaction nor cell accumulation around the cyst. A cross section of peripheral nerve presented no abnormality.

Anatomical diagnosis. Extradural basilar abscess; multiple bronchiectatic abscesses in lungs; bronchopneumonia; *Cysticercus tenuicollis* adherent to broad ligaments *Thysanosoma actinioides* infection, biliary hepatitis; emaciation, irregular incisor teeth. *Sarcocystis tenella.*

Case No. 2. Male, yearling sheep on Briggs-Ellis Ranch; Mr. Vestal's house; Big Timber, Montana. September 28, 1903.

This animal was picked out from the same bunch of invalids as No. 1, it being considered about the worst locoed member of the band except No. 1. The sheep had been at Vestal's Ranch for nearly two weeks, having been brought from a distant ranch on account of their sickness. Like the other sheep in the bunch, this one was undersized, thin, emaciated, walked with a weak gait, the hind legs held rather far apart and the legs being used in a slightly clumsy manner, somewhat suggesting the idea that the animal was walking on stilts. Not all the animals had equal difficulty in walking, some going with perfect ease. Some of the weaker animals looked dull and apathetic. None seemed to be nervous, or excitable, except No. 1. The animals did not show any tremor. They fed naturally, and fairly constantly. Rough tests indicated that hearing and sight were normal and no abnormalities of sensation or of reflexes could be detected on superficial examination.

It must be noted that the appearance of No. 1 was markedly different from that of the other members of this flock and that the others showed differences among themselves. The only symptoms which seemed fairly constant were (1) thinness or even emaciation, and (2) weakness shown in the slow, uncertain gait and the awkward posture when standing.

No. 2 being typical of a dozen others in the bunch, was chloroformed, and at the same time the jugular vein and carotid artery were cut. Postmortem examination was made at once at 3 p.m., September 28.

Autopsy No. 2. The yearling measured from tip to tip about one yard. Weight less than 15 pounds. Emaciation extreme. Skin, eyes, nose, head and ears presented no abnormality. Incisor teeth were loose, and irregular in size and location. The molar teeth were very black. The interstices between the teeth were filled with tough, blackened fiber. Subcutaneous and peritoneal fat very scanty. Peritoneal surface smooth and glistening. In peritoneal cavity were found from 50 to 100 cc. of clear fluid, and eight soft, clear, watery parasitic cysts between 2 and 6 cm. in diameter were between the folds of the omentum. The cysts had no relation to vessels or other structures and were filled with a soft, gelatinous, material containing one short, ringed, cylindrical, worm-like structure, 0.25 to 0.5 cm. in length, 0.25 cm. in diameter, from which fine threads reached out into the jelly. At the rounded end of this worm-like structure was a linear depression. Two or three smaller cysts were found elsewhere, two being between the liver and diaphragm, and one forming the center of an adhesion between the gall bladder and the small intestine.

The common bile duct was distended, being as large as a lead pencil. On opening it a flat worm was found completely filling the duct, looped on itself with the head in the lower half of the cystic duct. The rest of the cystic duct was clear. The loops of the worm filled the hepatic duct, extended into several main branches of the hepatic duct and for quite a distance up into the liver and also along the duct of Wirsung for 2 or 3 cm. into the pancreas. Loops of the worm also extended into the intestinal canal.

The liver was of about the same size as that of sheep No. 1. Surface was smooth except for the adherent cyst above described, consistence moderately firm. Just to the left of the median sulcus of the anterior margin was an irregular wedge with the broadest surface toward the edge of the liver, measuring 6 x 8 cm., rough, firm, of scar-like character, pale, yellowish on section and sharply marked from remainder of liver. On section of liver the main branches of the bile ducts were filled with tape-worms.

Spleen measured 10 x 6 x 2 cm. It was smooth, soft, and normal on section. Kidneys were alike, the capsule stripped off readily leaving a smooth surface. On section the cortex measured about 8 mm. The glomeruli were fairly distinct, the pyramids pale, the kidney apparently normal. The adrenals 2 x 1 x 0.75 cm. were bean shaped, with pigment in their surfaces. On section, cortex and medulla were clearly marked, uniform, and apparently normal. Pancreas was soft and friable but presented no abnormality except for the worm in the duct. Bladder was empty and contracted; the mucosa pale. Aorta elastic and apparently normal. Heart. The pericardial sac contained free within it a cyst like those described above. Pericardial fluid not increased. Fat reduced. Surfaces smooth and glistening. The valves were clear and delicate; Foramen ovale closed; myocardium was pale, semi-translucent and brown. The lungs were alike. There was no free pleural fluid. The pleural surfaces were smooth and glistening. The lungs were small, crepitant, cushiony. The bronchi and vessels were clear and pale. On section, the lungs were pink and of uniform appearance except for one or two small patches of emphysema. The brain and cord presented no abnormality. The nares and adjacent sinuses were clear throughout. The trachea and esophagus were normal. The paunch was filled with hay and grass well chewed. The other stomachs were normal with the normal odor of gastric contents. In the duodenum were found several heads of tape-worms apparently four in all, with a great many segments. The rest of the intestine contained normal looking contents. The mesenteric lymph glands were enlarged, soft, pale and apparently normal on section.

Microscopic report. Heart. Section stained well, heart muscle cells for the most part were distinct though slightly granular and a number of the fibers had a wavy contour. Here and there were found cysts, maybe one-half dozen altogether embedded in the muscle and showing no reaction around them. The lung tissue was vesicular and normal. Some of the lung vessels contained an excess of leukocytes.

Liver. The liver cells were large, somewhat vacuolated and granular. The bile ducts were dilated and lined with high columnar epithelium showing abundant goblet cells. The surrounding tissue was slightly edematous and occasionally peculiar cells and debris were found in the lumen of the bile duct, apparently desquamated-epithelial cells. The lobules could be recognized fairly distinctly; the central two-thirds of the lobule stained deeper than the outer third, the outer third showing cells more vacuolated, paler and more granular and containing more

yellow pigment than elsewhere in the lobule. In some instances the nuclei in the outer zone of the lobule had entirely disappeared leaving a yellowish pink granular group of cells. In another block from the liver the cells showed the same changes, and, in addition, there was a definite increase in the fibrous tissue around the bile duct and dense accumulations of cells in this region with indications of rather rapid new formation of a fibroblastic tissue. A nodule was found quite sharply marked off, composed for the most part of newly formed fibroblastic cells. A third block from the liver showed again the accumulation of cells around the bile ducts with a beginning fibrosis extending from the ducts into the liver tissue. The degeneration in the outer zone of the lobule was also seen, though not very distinctly. Another section of liver passed through a nodule of very cellular appearance, sending a number of branches into the adjacent liver. In this mass were compressed liver cells and strands of liver cells. Great numbers of fibroblastic cells, chiefly young, with large vesicular nuclei, and dense accumulations of lymphocytes together with a small number of polymorphonuclears occurred. There were also a number of eosinophiles. At the edges of this nodule the infiltrating cells were seen in between the liver cells very clearly, but it was very difficult to decide whether the cells were chiefly in the lumina of the capillaries or packed between the capillary wall and the liver cell. Both situations appeared to be commonly occupied. Here and there a capillary was found which undoubtedly was plugged by a mass of small deeply stained cells whose nuclei had the appearance of lymphoid cells. Among these occassionally was met a large, pale, oval or rounded nucleus.

The kidney showed cloudy swelling and slight congestion. The adrenal showed pigmentation in the capsule with, apparently, islands of adrenal cells here and there in the capsule. The large vacuolated cells of the medulla also contained dots of brown pigment. A few cysts were found embedded in the muscle of the diaphragm.

Anatomical diagnosis. Infection with *Thysanosoma actinioides;* obstruction of common bile ducts, cystic, hepatic, and pancreatic ducts; degeneration (infarction?), of a wedge-shaped section of liver with organization, biliary hepatitis; infection of pericardium, liver capsule and omentum with *Cysticercus tenuicollis;* loose irregular incisor teeth; emaciation, *Sarcocystis tenella* in heart muscle and diaphragm. Cloudy swelling of kidney. Leukocytosis.

Case No. 3. A flock of 2000 sheep, which had just been driven in from the range to be picked over for the winter, was examined. The flock contained 500 to 800 lambs and yearlings. The sheep herder and the owner (Mr. Vestal) estimated that nearly one-half of the lambs and yearlings were locoed. The examination of the sheep in their corral showed that more than one-half, adults and young ones alike, suffered from coryza and bronchitis. At least one-half of the lambs and yearlings were emaciated and moved with a stiff-legged gait. The sheep were more or less sluggish and certainly many of them were very weak. They were not tremulous. They showed no signs of eye or ear defect nor was there any evidence of excitement or mental disturbance. They kept in a bunch and did not tend to wander off to the sides of the corral. Not only the young sheep but many of the older ones were unhealthy looking, one of them being so weak it could not rise to its feet. A lamb about five or six months old which appeared as severely affected as any that could be found was picked out, chloroformed, bled from the carotid, pelted, and examined at once.

Autopsy No. 3. September 29, 1903. Lamb, female. Length about 2½ feet from tip to tip. Weight hardly more than 12 pounds. Subcutaneous fat practically absent.

Muscles pale, translucent, reddish brown. Peritoneal surface smooth and glistening. No excess of fluid, one parasitic cyst found in peritoneal cavity.

Heart. Epicardial fat very slight in amount, surfaces smooth and glistening, valves clear and delicate, foramen ovale closed. Myocardium translucent, reddish brown. The free margin of the left aortic leaflet presented a line of pigmentation. Lungs free from adhesions, pleural surfaces smooth. The color of the lungs in general was pink with here and there small groups of emphysematous cells appearing gray. On the surface of each lung were two or three areas from 0.25 to 1 cm. in diameter which were firmer, irregular, slightly darker red than surroundings and apparently consolidated. On section, the lung elsewhere appeared pink, the bronchi and vessels appeared clear except for the firm dark red areas. Spleen was small, smooth, soft; the structures showed well on section; condition apparently normal. Liver was small, surfaces smooth, the edge moderately firm and sharp; color, brownish red, semi-translucent. On section, appearance was uniform. The lobules were not distinct. On the convexity of right lobe of liver a pin-head sized whitish fibroid nodule was met with. Kidneys appeared pale and normal but under the capsule there were one or two fibroid nodules, 1 or 2 mm. in diameter embedded in the cortex. Pelvis and ureters clear. Bladder empty. Mucosa pale. Ureters, tubes and ovaries small and normal. Pancreas soft, friable, apparently normal. Digestive tract contained normal food in abundance and showed no lesion. Brain and cord apparently normal. No excess of fluid. No adhesions. The sinuses connected with the nose were empty and clear. There was a slight muco-purulent exudate over the turbinate bones. The incisor teeth showed irregularities in position and were loose, otherwise mouth was clear. Mesenteric fat and body fat in general was very greatly reduced. The adrenals were bean-shaped with dark pigmentation over the surface showing the cortex and medulla clearly on section. Hemolymph glands were numerous, pin-head in size.

Microscopic report. Heart. Striations and fibrillations distinct. Muscle cells slightly granular, otherwise apparently normal. Two or three small sarcocysts were found. In two instances the cyst occurred in a Purkinje cell. Lung apparently normal; section from nodule not obtained.

Liver. The section was distinctly cloudy. The liver cells were large, frequently vacuolar and granular. The bile ducts were distended, though only to a slight degree. The blood in the portal vessels contained an excess of leukocytes, quite a number of which were eosinophilic and in addition there was a distinct increase of lymphocytes in the portal blood. The peribiliary tissue was edematous and contained a small number of cells, partly lymphoid, partly eosinophilic.

Spleen, slightly congested, otherwise normal. The kidney tubules were lined by cells which were markedly vacuolated; otherwise the section was normal, except for the nodule in the cortex. A section through one of the white nodules described in the autopsy report showed that the nodule was embedded in the cortex of the kidney. In the center of the nodule was a small focus of coagulation necrosis with fragmenting nuclei surrounded by fibroblasts and mononuclear cells, some of which were lymphoid in character, others larger, and like mononuclears. These large and small mononuclear cells, mingled with fibroblasts, extended quite a distance between and compressed tubules. In the nodule were found three chief foci of coagulation necrosis and two or three smaller ones. The fibroblasts appeared to form a complete capsule immediately around the foci of necrosis. Outside of this infiltration became much

more diffuse. One or two large cells were met with at the very edge of the area of coagulation necrosis which had an abundance of pink cytoplasm and contained a considerable number of nuclear fragments. They did not, however, suggest the giant cell of tuberculosis. The fibroblastic tissue did not seem to be especially rich in capillaries. Among the cells were a good many with eccentric nuclei and rather pinkish purple cytoplasm, apparently of the plasma cell type but unusually large for plasma cells. Adrenal, apparently normal; diaphragm showed no cysts. Bone marrow showed an excess of giant cells, and of cells of the myelocyte type. Lymph gland showed hyperplasia of the cell nests with crowding of lymph cells in the outer zone of gland. The sinuses in the central part of gland were widely dilated, and contained large vacuolated endothelial cells having a cloudy, degenerating appearance.

Anatomical diagnosis. Emaciation; irregular incisor teeth; *Cysticercus tenuicollis* in peritoneal cavity; catarrhal inflammation of nares; patches of recent bronchopneumonia. Inflammatory nodules in kidney. *Sarcocystis tenella* in heart. Peribiliary cirrhosis; degeneration of outer zone of liver lobule. Lymphoid hyperplasia.

Case No. 4. At Mr. Clifford Kelly's ranch, Hunter's Hot Springs, Montana.

The sheep herder brought in a very sick yearling from the range, remarking, "if this is not a locoed animal, I have never seen a case of loco." The animal was thin, weak, stiff-gaited, dull, apathetic, with a rather rough fleece.

Autopsy No. 4. October 14, 1903. Animal bled to death and autopsied at once. Female sheep, greatly emaciated. Feet were apparently normal. There was an extensive area of extravasation and edema over the buttocks. Subcutaneous fat very greatly reduced. Muscle pale, translucent, apparently normal. Peritoneal surfaces in general smooth and glistening except for adhesions. No excess of fluid. Peritoneal fat greatly reduced. No cysts free in peritoneal cavity. Pleural cavities contained no excess of fluid. No adhesions. Right and left lungs were moderately voluminous, pale, pink, crepitant; vessels clear. On opening into the smaller bronchi a number of fine worms were found together with a considerable amount of thick, viscid, mucus. The worms were approximately an inch long, and as thick as medium or coarse, cotton thread, were motile, white with a dark line running spirally from head to tail. Six were removed from one bronchus. On the surface of lung were one or two raised, dark red, firmer areas not very sharply marked off and consolidated. On section a nodule of consolidation was found to communicate with the bronchus containing worms. Pericardial cavity contained small amount of clear, yellow fluid. Pericardial surfaces smooth and shining. Fat very slight in amount. Heart valves clear, delicate. Foramen ovale closed. Myocardium, pale, brown, translucent. Spleen small, surface smooth, consistence soft. On section, dark reddish brown. Malpighian bodies and trabeculae clearly seen. Liver. Between diaphragm and liver, over the whole of the anterior (ventral) surface were firm adhesions in which were cavities containing 50 to 100 cc. of slightly turbid, yellowish, bile-stained fluid together with two or three fairly large, firm, elastic clots 10 or 15 x 1 or 2 cm. in size. This mass of adhesions, etc., was in relation with an ulcerating surface on the liver which showed best on section through the liver. On section, there was found in the middle of the main lobe an ulcer 3 or 4 cm. in diameter, firm, slightly projecting, pale gray, fleshy looking, with irregular margins extending deeply into the lobe. In the center of this area was a necrotic rough-walled cavity, bile stained, about 2 x 3 cm. Elsewhere the liver was brown, moderately soft, and showed little alteration. Gall bladder apparently normal. Bile ducts empty. Stomach contained a normal amount of food. The lining

of the stomach was everywhere smooth and pale. In the upper part of the duodenum were found numerous flat worms, the total length of which amounted to some five or ten meters long. These apparently represented three or four worms which were like the liver worms described previously (fringed tapeworm). Rest of the bowel normal, but contained an excess of sticky mucus. The front teeth were set crooked to the gum, and were loose; mouth and esophagus clear. The mucosa of nasal cavities was injected, slightly ecchymotic and covered with a sticky mucus. The ethmoid and frontal sinuses were clear.

Kidneys were alike, and appeared normal. Bladder contracted, empty, apparently normal. Internal genitalia apparently normal. Brain and cord presented no abnormality.

Microscopic report. Heart showed quite a large number of sarco-cysts like those previously described. Most of them were within heart muscle cells. One, however, was found in the space between two groups of muscle bundles. Heart muscle otherwise normal. Lung. The bronchial mucosa stood out clearly and showed no alterations. The bronchial walls were clear. The lung, everywhere vesicular except for one small focus in which possibly as many as a couple of dozen alveoli were filled with red blood corpuscles. Among the corpuscles and in the alveolar walls were a moderate number of polymorphonuclear leukocytes. It appeared that the chief infiltration with leukocytes was into the alveolar wall. One or two alveoli contained a great excess of desquamated epithelial cells. In one alveolus these cells were packed together, well stained, and almost looked as if they were growing in the alveolus.

Liver. Section 1 passed through a necrotic region of liver and showed in the margins great irregular proliferation of bile ducts and a large bile duct with papillomatous changes in the mucosa together with infiltration of the surrounding tissue by large and small mononuclear cells, eosinophiles, and eosinophilic mononucleated cells. Around the dilated duct the necrotic liver tissue exhibited regions in which hemorrhage was abundant, and many regions where very great fibroblast formation was occurring. The section extended from the liver to the diaphragm. Between the liver and diaphragm was necrotic debris in which was considerable fibrin, many polymorphonuclear leukocytes, fragments of nuclei, and yellowish brown material apparently disintegrated red blood cells. Many of the polymorphonuclears took a bright acid stain. Granulation tissue was forming from the diaphragm and extending into the exudate between liver and diaphragm. Throughout the section the replacement of liver tissue by a watery and cellular fibroblastic tissue was marked. In this fibroblastic tissue, atypical bile ducts were abundant. Other sections through liver and diaphragm gave findings practically the same as those described. In addition there were numerous sarcocysts in the diaphragmatic muscle.

Spleen apparently normal, pulp very cellular. Pancreas. The cells were large, very much vacuolated, at first sight reminding one of the adrenal. The definite arrangement into glands and acini was obscured by the tremendous swelling of the cells. There was, however, no evidence of necrosis, the nuclei for the most part were fairly well preserved although they were rather vesicular with dots of chromatin around the margin, and occasionally they were pyknotic. Kidney. Glomeruli unaltered, moderately full, tubules of cortex very cloudy, pale and vacuolated, frequently showing abundant albumin in the lumen. Adrenal apparently normal, capsule pigmented; eosinophilic cells were seen between cortical cells. The capsule and peripheral sinus of the lymph gland were apparently normal, the cortical zone was uniformly

composed of dense masses of lymphoid cells except that here and there a germinal center stood out as a pale pink focus in the cortex. All of the central sinuses were very widely dilated and contained free cells. The cell columns were reduced corresponding to the dilatation of the sinuses. Under high power the center of one of the germinal centers showed a moderately large amount of slightly stringy, rather homogeneous deep pink hyaline material in which were only a few cells; around these were a number of large, vesicular nuclei, oval or round, which formed several layers not sharply marked and mixed more and more with lymphoid cells as one passed from the center to the periphery. Small masses of interstitial hyaline were also found in the cortex elsewhere than in the cell nests. The cells in the dilated sinuses appeared to be large desquamated epithelial cells which were often phagocytic. The sinuses also contained a moderate number of polymorphonuclear eosinophiles and lymphoid cells.

Section through a small hemolymph gland about 3 mm. in diameter showed that the peripheral sinus was dilated and packed with red cells, the central sinuses were not nearly so dilated as in the cases previously recorded but most of them were packed with red cells. A distinction into germ centers and cell columns could not be made out, the section appearing to be made of the sinuses distended with red blood cells and of intervening diffuse, cellular tissue in which a light reticulum could be made out. As seen under the high power, the cellular tissue seemed to be chiefly made of cells of a lymphoid type and of variations from this type. Endothelial cells phagocyting red corpuscles were common. Bone marrow showed an increase in polymorphonuclears, many of which were eosinophilic, and an increase in cells of the myelocyte type. Section through the thyroid showed a number of acini containing bluish pink secretion, the acini being lined by vacuolated cuboidal or low columnar cells. There were many small acini.

Anatomical diagnosis. *Thysanosoma actinioides* infection; abscess of liver with sub-diaphragmatic abscess; fibrosis in liver; vacuolization of pancreas cells and kidney; emaciation; loose and irregular incisor teeth; verminous pneumonia, *Strongylus (Meta-strongylus) filaria*; *Sarcocystis tenella*. Lymphadenitis.

Partial autopsies were performed upon three of the healthier invalid lambs on Mr. Cliff Kelly's ranch. All three died from experimental doses of cavadine (death camus) administered by Professor Chesnut.

Autopsy No. 5. This animal was infected with *Thysanosoma actinioides* and showed a small caseous-cystic cavity in the apex of the right lung.

Autopsy No. 6. The fringed tape-worm was present in this animal also, together with organizing bronchopneumonia, and sarcosporidiosis.

Autopsy No. 7. No worms were found in a partial autopsy of this animal. Microscopically, there were great numbers of sarcocysts in the heart muscle and diaphragm.

Case No. 8. October 15, 1903. Mr. Clifford Kelly's ranch. A number of badly diseased sheep, regarded as cases of "loco" were confined to a pen and fed with locoweed for a short while. One was examined, which had been fed for two weeks on freshly plucked locoweed, occasionally receiving also a little alfalfa. Before autopsy it was observed that there were no special symptoms. Pupils were not dilated nor contracted. The animal presented exactly the same features as the other animals which had not been fed on loco. It ate by preference alfalfa but also ate the loco which was put in the corral. Animal emaciated and stiff. Bled from carotid, skinned, and autopsied at once.

Autopsy No. 8. Very much emaciated animal. Fleece rough and poor. Subcu-

of the stomach was everywhere smooth and pale. In the upper part of the duodenum were found numerous flat worms, the total length of which amounted to some five or ten meters long. These apparently represented three or four worms which were like the liver worms described previously (fringed tapeworm). Rest of the bowel normal, but contained an excess of sticky mucus. The front teeth were set crooked to the gum, and were loose; mouth and esophagus clear. The mucosa of nasal cavities was injected, slightly ecchymotic and covered with a sticky mucus. The ethmoid and frontal sinuses were clear.

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Autopsy No. 8. Very much emaciated animal. Fleece rough and poor. Subcu-

taneous fat almost absent. Muscles pale, Recti were semi-translucent. Peritoneal cavity contained about 100 cc. of clear yellow fluid. Common bile duct, cystic, hepatic, and pancreatic ducts were filled with tape-worms and dilated to a diameter of about ½ inch. The worms extended a very short distance into the duodenum. Liver was smooth and apparently normal except for the dilatation of the ducts. In the omentum were found several gelatinous cysts and one cyst similar to these was found encapsulated on the surface of the liver. This cyst was more or less dried up into a somewhat cheesy mass. Diaphragm clear. Pericardial cavity contained 10 or 20 cc. of clear fluid. The surfaces were smooth and glistening. Heart valves delicate and normal. Pericardial fat greatly reduced. Myocardium, pale brownish red, semi-translucent. In the substance of the left ventricle was found a caseating nodule similar to that on the surface of the liver. Pleural surfaces smooth and glistening. Lungs were only moderately voluminous, pink, and crepitant throughout. No nodules present. Trachea and bronchi and bronchioles free from mucus and from worms. Vessels at the root of the lungs were clear. On section lungs were normal. Spleen small, surface smooth, consistence soft. On section dark reddish brown; malpighian bodies and trabeculae well made out. Kidneys were alike. Capsules stripped readily leaving smooth, pale surface. On section, the glomeruli and striations were faintly seen. Pyramids were pale. Mesenteric lymph glands were large, soft, and pale, frequently showing on section a rather dark gray medulla. Adrenals appeared normal. Esophagus clear. The first stomach contained about two or three quarts of food in which could be recognized a very small amount of locoweed in a large amount of hay. All four stomachs and intestines were apparently normal showing a slight amount of rather sticky mucus about the middle of the jejunum. No stomach worms were seen nor any worms in the intestine. The sinuses connected with nose appeared clear, the mucosa pale except that in the frontal sinus was found a fly larva. The front teeth were loose, long, and irregular both in length and position. The gums appeared normal, pale and firm. There was no evidence of suppuration nor of foreign material at the roots of the teeth. The brain and its membranes appeared clear throughout. Surfaces of brain and medulla were pale and normal. No excess of fluid. Convolutions prominent. No sign of pressure. No discoloration of brain or medulla. Internal genitalia appeared normal. Hemolymph glands stood out plainly, apparently were not enlarged. The intima of aorta was uniform and unchanged.

Microscopic report. Heart, the striations and fibrillations were distinct, especially striations. The undifferentiated central region of heart muscle cells appeared to be unduly large but the pigmentation was not increased. The section contained a large number of cysts located within heart muscle cells, one was found within a large undifferentiated Purkinje cell. In another section of heart, the nodule described in the autopsy was met with. In the center of the nodule was a mass, apparently the cross section of a parasitic worm or embryo. Around this was bluish purple debris with a space between the parasite and the debris. The purple material ended sharply in a zone of fibrillated, pinkish debris, apparently necrotic heart muscle. This passed over rather sharply into relatively normal heart muscle. In the intermediate zone between the debris and the heart muscle there was fibroblastic tissue with large and small lymphoid cells collected here and there. The growth of fibrous tissue was not uniform throughout the periphery of the nodule but could be clearly made out at several points. In one or two regions it was definitely becoming flattened in the direction

of forming a capsule around the embryo. The mononuclear and polymorphonuclear infiltration was extremely slight compared with the size of the embryo.

Liver. The structure was not obvious, all of the cells being greatly swollen with corresponding reduction of capillaries, most of which were nearly or quite obscured. The liver cells were swollen, granular, and vacuolated. A second section showed that there was a slight dilatation of the ducts, the duct epithelial cells being large with pale, vesicular, bluish nuclei. Occasionally it appeared that there was a slight degree of edema around the ducts, especially the larger ones, but there was no noticeable fibrosis. In only one or two instances, after searching through two sections, could regions be found in which there was an accumulation of cells around the duct. These cells were chiefly mononuclears of a rather large size with moderately abundant cytoplasm. Spleen apparently normal. Cytolysis of red cells observed. Kidney showed granular epithelium, otherwise normal. Section of lymph gland showed the cortex with very little differentiation between germ centers and cell columns. The deeper part of the gland showed very great dilatation of the sinuses with reduction in the amount of lymphoid tissue between the sinuses, the result being that this part of the gland looked almost like spongy tissue. It could be seen with particular clearness in this section that the sinuses were lined with large, cloudy, pink cells, frequently cuboidal, containing a large, moderately deeply stained but rather vesicular nucleus. These cells were frequently present free in the sinuses, sometimes singly, sometimes in clumps. The sinuses also contained free lymphoid cells. The large cells occasionally contained a large amount of coppery yellow pigment, especially when the cells were free in the lumen. The appearance of the lymph sinuses, owing to this peculiar arrangement of the lining endothelium, suggested at first sight adeno-carcinoma. The blood vessels in the glands were empty or showed only normal contents.

Anatomical diagnosis. *Thysanosoma actinioides* infection of liver and pancreatic ducts; emaciation; loose and irregular incisor teeth; *Cysticercus tenuicollis* with caseating cysts in capsule of liver and heart; larva (*Oestrus ovis*) in right supraorbital sinus. Hyperplasia and phagocytosis in lymph gland. *Sarcocystis tenella.*

Case No. 9. This was a badly locoed sheep from Mr. Cliff Kelly's invalid band which had been fed on locoweed especially for purposes of experiment but presented no alterations as the result of such feeding, and evidently did not like the weed as a diet. The animal was dull, emaciated, stiff-legged and weak and had a slight coryza. October 15, 1903, was bled from the carotid and examined at once.

Autopsy No. 9. Fleece rough and ragged looking, front teeth loose and irregular. Superficial examination negative. Fat almost absent. About 100 cc. of clear yellow fluid in peritoneal cavity. Peritoneal surfaces smooth and glistening. Several gelatinous cysts with motile embryos were seen in the peritoneal cavity. The common bile duct, the cystic and hepatic ducts were tightly packed with tape-worms. The diaphragm appeared clear, muscles red, uniform, translucent. Pericardial fluid 10 to 15 cc., clear yellow. Pericardial surfaces smooth and glistening, the fat greatly reduced. Myocardium reddish brown, translucent, valves clear and delicate. Foramen ovale closed. Pleural surfaces dry and pale, free from adhesions. Lungs alike, not very luminous, pink, crepitant, and free from nodules. Vessels at the root of the lung were clear. Trachea and bronchi pale, containing a slight amount of sticky mucus. In the finer bronchioles were one or two small thread like structures apparently young worms around which there was very little reaction. Spleen smooth, soft, small. On section, malpighian bodies and trabeculae clearly made out. Liver smooth,

moderately soft, dark. On section, negative except for dilated bile ducts. Kidneys alike. Capsule stripped readily leaving a smooth pale surface. On section, the cortex was pale and brownish gray. Glomeruli faintly seen. Appearance on section normal. Adrenals and hemolymph glands were like those in the previous autopsy. The bladder empty and apparently normal. Pancreas soft, apparently normal.

The fourth stomach contained many fine worms which were free on the mucosa. No encysted forms could be made out in the surface of the mucosa. The mucosa of all four stomachs and the intestine was everywhere pale and smooth. The mucosa of the nasal chambers was injected and coated with a slight amount of sticky mucus. The sinuses connected with the nose were apparently clear and normal. The brain and its membranes showed no abnormality.

Microscopic report. Lung. The section showed vesicular lung tissue. Liver cells were greatly swollen, vacuolar, and granular; the alignment less definitely preserved than usual, capillaries greatly reduced or often collapsed as the result of swelling of liver cells. The cells in the outer zone of lobule were possibly slightly more granular than the others; the nuclei in the outer zone being frequently very pale or even lost. The difference between the outer zone and the rest of the liver lobule was not as conspicuous as in preceding autopsies. Bile ducts showed very little alteration and were inconspicuous; they were not notably dilated and there was no increase in the surrounding connective tissue. Kidney showed slight cloudy swelling of convoluted tubules. Spleen normal.

Anatomical diagnosis. Thysanosoma actinioides infection; dilatation of bile ducts; granular and vacuolar degeneration of liver cells; emaciation; loose irregular teeth; infection of stomach with wire worms (*Ostertagia marshalli*); recent infection of lung with *Strongylus* (*Metastrongylus*) *filaria; Cysticercus tenuicollis.*

Autopsies 10 and 11 were only partial autopsies performed October 15 at Cliff Kelly's ranch, one of them (No. 10) upon an animal which had received a plant poison, the other (No. 11) upon a locoed animal which had been receiving special doses of loco, without appreciable effect. The autopsies disclosed the presence of the bile duct tape-worm and the wire worms in the fourth stomach of each animal and the lung worm apparently fresh in the lungs of the "locoed" animal. On microscopic examination of the tissues from case No. 11 sarcosporidia were found in the heart muscle and diaphragm; there was vacuolar and granular degeneration of the outer zone of the liver lobules; the kidney, spleen and stomachs appeared normal.

The sheep just described were studied during the autumn of 1903, and furnished the basis of a report to the Department of Agriculture. During the summer of 1904 examinations were made of a number of sheep selected by the ranchmen from diseased flocks, and regarded as examples of severe loco disease. Descriptions of these cases follow:

Olie Chrest of Howie, Montana selected two "locoed" sheep from his herd for examination. The animals were emaciated, and stiff-legged with ragged fleeces. Their front teeth were loose and irregular. They were regarded as typical locoes. Yearling A was bled to death.

Autopsy No. 20. At autopsy August 23, animal showed absence of fat; there were several young larvae of *Oestrus ovis* crawling over the turbinated bones; there were

small calcified cysts in the myocardium. The liver showed dilated and thickened bile ducts with *Thysanosoma actinioides* in the intestine. Worms supposed to be *Strongylus filicolis* were found tightly attached to the mucosa of the large intestine.

Microscopic report. Heart showed the presence of several sarcocysts. A small structureless mass encapsulated in a fibrous capsule was found in the heart muscle. This cyst, not more than 3 or 4 mm. in diameter was seen at autopsy. Lung apparently normal except for one patch of bronchopneumonia in which there was considerable hemorrhage surrounded by cellular exudate. Liver showed slight vacuolization of the cells in the outer zone of the lobule. No bile ducts appeared in section. Kidney appeared normal.

Yearling B, of Olie Chrest, was shot on August 26 and autopsied at once.

Autopsy No. 21. The animal was thin but not emaciated. The bile ducts were markedly dilated and packed with masses of "fringed tape-worms." The lymph glands of the mesentery were large, soft and grayish brown. Two hair balls about 3.5 cm. in diameter were found in the fourth stomach and in addition many wire worms, none of them firmly attached, were found in the fourth stomach. On opening the kidney two calculi of firm brownish material were found in the calices. The nares contained about two dozen small Oestrus larvae about 2 mm. in length. The mucosa was moderately engorged and swollen and covered with thick tenacious muco-pus.

Microscopic report. Heart unusually thickly studded with sarcocysts of varying size. Lungs clear except for miliary regions in which red blood cells had extravasated into the alveoli. These regions were so numerous as to give a peculiar dotted appearance to the section. No leukocytes appeared with the extravasated reds. The same appearance was seen in sections from several different parts of the lung. Liver appeared practically normal, except for thickening of a large bile duct. The small bile ducts appeared unaltered. Spleen apparently normal, Malpighian bodies conspicuous, pulp cellular. Kidney apparently normal. Voluntary muscle showed a number of sarcocysts, not however nearly so numerous as in heart.

The following cases are interesting as they point to an infectious variety of "loco disease." Two years ago (1902) a ranchman (Mr. T.) failed on account of losses from loco disease, his sheep being at the time on the ranges of B. O. Forsyth, of Busteed, Montana. One year later, another rancher (Mr. V. C.) had heavy losses from loco while using the same range. During this year (1904) Forsyth, using the same ranges, found over 1200 cases of loco disease among his sheep, two year olds and adults suffering chiefly. He has now moved to another range. He sent three of his most severe cases of loco disease for examination.

The sheep were by no means in such wretched condition as many others which had been studied, and one or two other ranchmen considered that they were not severe "locoes." They were thin, but not emaciated; only one walked with the usual stiff-legged gait; there was no cough; the fleece was even and thick, and while one was evidently ill, the general appearance and behavior of the other two was not that of ill animals, though they would not be called large or vigorous.

August 27, 1904, one of Forsyth's sheep was shot and at the same time bled from the carotid.

Autopsy 23. Postmortem at once. The sheep was thin but not emaciated, there was a heavy infection with *Thysanosoma actinioides* in the common and hepatic ducts; over fifty-six small wire worms were found in the fourth stomach. The incisor teeth were long. There was a small amount of black sand in the pelvis of the left kidney. Hemorrhagic spots were found in the lungs and there was a hair ball in the fourth stomach measuring about 4 x 2 x 1.5 cm. On microscopic examination small sarcocysts were found in the myocardium; and pin point areas of extravasation into the alveoli of the lung. The liver cells were distinctly vacuolated, the capillaries being indistinct and compressed. Even the small bile ducts were altered, but the change was more marked in the larger ducts. These were distended, frequently filled with exudate and surrounded by cellular and fibroblastic tissue. The fibroblast formation was only moderate and had invaded the liver tissue to only a slight extent. The cells surrounding the bile ducts were polymorphonuclears, large and small lymphoid cells and fibroblasts. An increased number of polymorphonuclears were present in the portal veins. Occasionally a small duct was found packed tightly with leukocytes so that the wall could hardly be recognized. The spleen showed cytolysis of red blood cells; the kidneys and adrenals were apparently normal. In a section through a lymph gland the sinuses were found dilated, as previously described, and containing eosinophiles, phagocytic endothelial cells and many granules of brownish pigment, like blood pigment. The voluntary muscle contained a few sarcocysts. Section of the fourth stomach showed no definite evidence of lesion from the wire worms; there was no reaction of an inflammatory character in the mucosa or sub-mucosa. Esophagus. Both epithelium and muscle wall appeared to be normal.

Autopsy 24. A two year old ewe from the Forsyth ranch was shot and at the same time bled from the carotid and autopsied at once on August 27. The animal was in fair flesh, the chief findings being that the common bile ducts and hepatic ducts were packed with *Thysanosoma actinioides* which also extended far back into the smaller liver ducts. The bile ducts were thickened and dilated and there were pin point hemorrhages into the mucosa. There was beginning necrosis of a wedge-shaped area on the cephalad surface of the right lobe of the liver. Twenty, or more, wire worms were found in the fourth stomach and Oestrus larvae in the supraorbital sinuses. There were small points of hemorrhage in the lungs. On microscopic examination the heart showed a moderate infection with sarcocysts, one of which was found in a large Purkinje cell. The lung and spleen appeared normal. The liver showed very marked changes especially in the region of the capsule of Glisson. At one place a widely dilated bile duct was cut across showing in the lumen a section through a tape-worm. The structure of the duct wall was practically lost and around the duct there was marked inflammation with necrosis of liver tissue, abscess formation and the evidences of chronic inflammation. Small regions of necrosis were scattered for quite a distance out from the main bile duct and the bile ducts all over the section showed thickening and infiltration around them. The outer zones of lobules were much more affected than the inner two-thirds except near the affected duct described above where lobules were destroyed. Kidney, cloudy. Cross section of lymph gland showed dilated sinuses and hyperplasia, as in previous case.

Jacob Hayem sent from his ranch two sheep which he said were badly locoed. The animals were thin and weak, weighing 25 and 35 pounds respectively. The fleece was good, there was no cough nor nasal discharge. There was only slight stiffness in gait. The incisor teeth were unusually long and widely separated. The field note was made that these animals did not present the usual appearance of the so-called "typical locoes" but would pass for specimens of poor stock which might improve if properly cared for during the winter. Compared with the experimental locoes they were pretty healthy looking animals.

Autopsy 27. At autopsy the smaller animal showed only a very large mass of tape-worm in the middle three-fourths of the small intestine. A field examination indicated that these worms were *Taenia expansa.*

Autopsy 28. The same tape-worm (*Taenia expansa*) was found in large numbers in the intestine of the second sheep in which also the bile ducts contained *Thysanosoma actinioides.* There was also infection with the *Oestrus ovis* together with abscesses in the lung.

Autopsy 29. August 31. The third sheep from Forsyth, a two year old, had been kept in camp for observation for several days. It appeared rather worse than either of the other two (Autopsy 23 and Autopsy 24), and was very thin. It was, however, active, alert, and free from stiffness. It coughed and sneezed very little, did not present the symptoms popularly attributed to the so-called typical loco, showing no twitchings, and having no tremor nor any special nervous symptoms. Hemoglobin 70 per cent by the Tallquist scale, temperature 102°, respiration 16 to the minute, pulse 116. At autopsy it was found to be infected with *Thysanosoma actinioides* causing dilatation and thickening of the bile ducts. There was *Oestrus ovis* inflammation to a slight degree and small wire worms were found in the fourth stomach. *Cysticercus tenuicollis* occurred in the peritoneal cavity. The animal was moderately emaciated.

The eighteen cases described above came from different ranches which were not very close together; the ranchmen were men of experience in sheep raising, and considered themselves, and were considered by their neighbors fully qualified to recognize loco disease. These ranchmen selected from bands of sheep containing many invalids the most typical and pronounced cases of loco disease, and turned them over to me for study. It seems hardly possible that every one of the ranchmen could have fallen into the error of selecting for me invalid sheep which more experienced sheepmen would not have looked upon as locoes. In fact, several opportunities arose to check up the diagnosis of one ranchman by that of another, and only minor differences existed between them. It is, then, reasonable to assume that the ranchmen made few, or no, errors of diagnosis, and that the sheep examined were fairly typical representatives of the armies of locoed sheep in Montana. A study of these sheep ought to reveal the symptoms characteristic of locoweed poisoning, and the autopsies should bring to light any striking anatomical changes produced by the use of the weed if such occur. It must be stated at once that neither of these objects could be accomplished.

The following signs and symptoms were observed:

1. Emaciation, in the majority of the animals selected. The other locoes from the same flock were undernourished, often stunted, not always emaciated.

2. Loose irregular incisor teeth, in nine out of eighteen cases. No note was made in the other cases of the condition of the teeth.

3. Weakness, and stiffness of gait in nearly all the very ill animals but by no means in all animals pointed out by the ranchers as typical locoes.

4. Dullness and apathy in the ill animals, but not in those less severely diseased. The iller animals were apt to wander off from the flock.

5. Tremor and nystagmus in one case (No. 1).

6. Coryza and bronchitis, in some flocks, not in all.

7. Rough, irregular fleece, occasionally.

Of these signs, the condition of the teeth is difficult to explain. The fairly constant findings, such as emaciation and under-development, weakness and stiffness, dullness and apathy are common to so many forms of disease that they have no value for the differential diagnosis of locoism. The coryza, bronchitis, etc., were sufficiently explained by the autopsy findings.

The clearest and most detailed clinical picture which the eighteen sheep allow us to draw is about this: The animals suffer from prolonged and progressive malnutrition; in the case of lambs, the animal is undersized; adult animals become thin or emaciated. As malnutrition becomes severe, the animal loses strength and energy, becomes listless, and does not keep up with the flock. As its strength diminishes the animal begins to walk in an awkward manner, the hind legs especially moving stiffly, as if they were parts of a mechanical toy. With these symptoms at least one-half the cases show loose and irregular incisor teeth. Now it is plain that, aside from the condition of the teeth, the above symptoms may result from any one of many causes which bring about malnutrition.

This forces us to the conclusion that typical and diagnostic symptoms of "Locoism" either do not exist or are so elusive that they escaped both my painstaking examinations and also the observations of the experienced ranchmen who gave their assistance. Inasmuch as the ranchmen were certain that the animals selected for study were severe cases of typical loco disease, there seems to be no escape from the above conclusion. It seems then that it will be either impossible, or exceedingly difficult, to construct the symptomatology of loco disease from animals studied on the ranches. Fondness for the locoweed is commonly regarded as the most constant and characteristic symptom exhibited by locoed animals, but even this was

not present in the sheep among which it was especially looked for; these sheep (Cases 8, 9 and 11), preferring other food, (alfalfa), and requiring to be partially starved in order to make them eat locoweed with any freedom.

Of other queer nervous and mental symptoms, commonly ascribed to loco, there was absolutely no trace in the sheep under consideration, except in one sheep with a brain (subdural) abscess.

The anatomical findings, like the clinical study, furnished nothing that helped to establish loco disease as a separate and independent disease. In all of the sheep examined there were evidences of more or less severe starvation. In fourteen cases the "fringed tape worm" (*Thysanosoma actinioides*) was found, and in two others its effects were seen. It caused definite liver lesions in nine instances, of which at least two cases were severe. (Cases No. 4 and No. 24.) Sarcosporidiosis occurred in eight cases out of the nine which were studied microscopically.

Cysticercus tenuicollis occurred certainly five times, and possibly more often.

The lung worm was found three times, the stomach worm seven times. Both were probably overlooked more than once. Pneumonia accompanied the presence of the lung worm once or twice. Small bronchiectatic abscesses in the lung occurred twice. An extradural abscess at the base of the brain was found in Case No. 1; in two instances (Cases Nos. 8 and 20) the remains of an embryo, supposed to be *Cysticercus tenuicollis* was found on the epicardium; an encapsulated focus of inflammation of unknown origin, possibly tuberculous was found in the kidney in one case (No. 3); hyperplasia of the lymph glands with dilated central sinuses was observed frequently and there seemed to be leukocytosis in two instances (Cases 2 and 23). Sheep fly larvae were found six times, none of the infections being severe.

Not one of the conditions observed at autopsy could conceivably be due to locoweed poisoning, with the exception of malnutrition. But it is far from certain that the weed was in any degree responsible for the emaciated condition of the sheep. There are other causes at hand to account for the emaciation and weakness. These causes are sufficient, in and of themselves, to account almost entirely, if not entirely, for the diseases among the sheep examined and also for the diseases among a very large number of sheep in Montana. It is extremely important to understand that the diseases encountered can be clearly explained without any reference to the locoweed whatever, and that the same diseases are known in parts of the world where locoweed does not grow.

First among the causes responsible for the poor condition of our sheep must be placed *insufficient food*, and second *parasitic diseases*. These two causes alone and in various combinations deserve the most careful consideration.

Insufficient food. It is beyond the scope of this article to discuss in detail the subject of sheep feeding. However, there was much evidence acquired during 1903 and 1904 which indicated that overstocking of the ranges was common. Frequently it appeared that there were too many animals on the ranges, and at the same time that the area of available range was becoming reduced. I was told by some men that the supply of natural forage was much less than it had been twelve and fifteen years earlier, and that the range grass was never given time to attain its growth before it was used again for grazing. I was told that it was not generally customary to rely upon alfalfa and other cultivated crops for food for the stock during inclement weather and at times when the range grass was scanty. I also learned that ranchmen raising large crops of alfalfa suffered relatively small losses from loco disease. In one instance I had a chance to observe that one division of a large flock of sheep grew thin and suffered severely from loco disease on the scanty forage of the plains, while another division of the same flock grew fat and prospered on the richer forage of the uplands. This evidence and more like it makes me agree with those ranchmen who hold that there is not enough natural forage to support all the live stock depending upon it, and that, therefore, malnutrition, or even starvation is not infrequent among the stock. In addition to this it was easy to observe, by watching flocks of sheep feeding, that the small and weak members of the flock are at a great disadvantage. In a flock of several thousand, the sheep, when feeding, are always on the move, staying together, several columns deep. The stronger animals keep to the front and get the best forage; the weaker animals at the rear eat what is left—which is poor rations when the range is short.

Parasitic diseases. Several of the parasites found in the "locoed" sheep occasionally produce serious losses. The fringed tape worm (*Thysanosoma actinioides*), the lung worm, and the fly larvae (*Oestrus ovis*) are well known scourges. The wire worm of the stomach is a newly discovered parasite and its exact relation to disease is unknown. Since it is very much like the *Strongylus contortus*, it seems probable that its effects will be similar. The *Strongylus contortus* causes widespread losses among sheep.

That sheep are infected with parasites does not mean that they must necessarily die of the infection. The severity of the resulting disease depends upon a number of factors, such as the *age* of the animal—young animals suffering more than full growns; the *general nutrition* and *health* of

the animal—under-nutrition and disease of any kind tending to enhance the severity of the parasitic infection. There are also other influential factors which are practically the same as the accessory etiological factors for loco disease, summarized in Section A. Varying degrees of starvation from underfeeding combined with varying intensities of parasitic infection are sufficient to explain the sheep diseases which I have studied, except for the curious condition of the incisor teeth which is unexplained, but seems to run parallel with the fringed tape-worm infections.

It must be pointed out, that, independent of my autopsy findings, there is strong reason to suspect that the Western ranges are heavily infested with parasitic diseases. The unhygienic conditions of the corrals and watering places, the custom of allowing dead sheep to remain unburied, and the unceasing use of the same grazing grounds year after year, without intermission, offer conditions favorable to the spread of parasitic diseases.

In concluding this section of the work, it may be stated by way of summary, that after careful study of severe and typical cases of loco disease it was not possible to collect a group of symptoms sufficiently constant and characteristic to enable the observer to distinguish loco disease from several other diseases; and there was no single characteristic anatomical change found at autopsy, which could be connected with the locoweed.

Moreover we were forced to the remarkable and paradoxical conclusion that the typical and severely "locoed" sheep, selected for us by various ranchmen, were not really suffering from locoweed poisoning, but from combinations of malnutrition and parasitic infection.

This leads us to the further conclusion that several different diseases pass for "loco disease" on the ranges. Some diseases which pass for "loco disease" have been mentioned above, others will probably emerge upon further study of Western live stock.

A further important conclusion forced upon us is that there is urgent need for a thorough-going technical medical survey of the ranges, to determine the existing forms of parasitic diseases and their extent, and to devise means to combat them.

In view of the findings recorded above, relatively little importance attaches to the answer to the ultimate question as to whether or not the locoweed is capable of producing a disease, which is independent of other diseases. Having found that 100 per cent of severe "locoed" cases examined were suffering from well known diseases other than loco poisoning I suspect that the locoweed has very little to do, directly, with the losses among sheep on the western ranges; but the evidence at hand does not justify an answer to the ultimate question, as to the existence of simple locoweed poisoning.

C. FEEDING EXPERIMENTS.

The campaign of 1903 established the facts that several menacing parasitic diseases are widely spread among the sheep of Montana; that these diseases, either of themselves, or in combination with insufficient food, are named "loco disease" by the ranchmen, regardless of the type of infection, or its severity; and that whatever symptoms the locoweed may cause can not be recognized accurately in sheep suffering from parasitic infection and underfeeding. If the effects of locoweed poisoning can be determined, it must be done in some other way than by the examination of sheep which the ranchmen call "locoes."

The Department of Agriculture directed me to continue the study of the loco problem during the summer of 1904, acting with the advice of Professor Chesnut and in coöperation with Mr. Reese of the Montana Agricultural College. It was decided to conduct a feeding experiment, and hold sheep in corrals where locoweed abounded, while others fed on alfalfa were kept as controls. Professor Chesnut, whose prolonged studies of the locoweed from the botanical side particularly fitted him for the purpose, selected Ten Mile Flat as the site of the experiment, for here the locoweed *Aragallus spicatus* (Hook.) Rydberg was unusually abundant, and other poisonous plants were absent.

Ten Mile Flat is a stretch of public land east of the Crazy Mountains and north of Big Timber, Montana. It has the reputation of being one of the worst locoed districts in this part of Montana. The soil is very poor and dry; there is a moderate amount of alkali, and the streams nearby are alkaline. The forage is quite scanty, a small amount of grass, wire grass and other plants occurring together with large patches of locoweed. From June until autumn the flat is very dry, and is exposed to the full effects of the summer sun. There was no shade where the experiment was conducted. In spite of its bad reputation, large bands of sheep are grazed over this flat every year. In the early spring of 1904, there was a moderate amount of grass to be found over the region, but this was quickly removed by two bands of from three to five thousand sheep apiece, which passed over this region before the middle of June. Another band was taken over soon after, leaving very little nutritious forage behind. Inquiries were made, but it could not be ascertained whether these bands suffered particularly from loco poisoning.

A large area with an abundant growth of locoweed was selected for use during the experiment. The objects of the experiment were: (1) To determine whether sheep can be poisoned by the locoweed when it is used as a food. (2) To determine the signs, symptoms and anatomical changes re-

sulting from loco poisoning, in case such poisoning can be brought about. (3) To determine how soon appearances of poisoning occur after the animals begin to feed on the plant. (4) To determine what diet is preferred by animals which have once learned to eat the locoweed. (5) To determine the relative importance of the various factors which the studies of 1903 had indicated were of influence upon the disease. These factors were age, general health, salt diet, partial starvation, and infections with sheep parasites.

Forty-three yearlings and nineteen ewes with their eighteen lambs were obtained from Mr. Paul VanCleve of Melville, Montana. Only healthy looking animals were taken. They were of medium size for their age, and were of mixed breed. The animals were dosed thoroughly with thymol and creosote in order to free them from intestinal parasites so far as possible; were brought to the experimental camp and placed in corrals, a numbered ear tag being attached to each animal.

Four pounds of alfalfa hay was taken to be a sufficient day's ration for one healthy sheep, and a supply of alfalfa hay was kept with scales beside the corrals, the rations for each corral being weighed out daily. Water was kept in the troughs in the corrals, the troughs being filled twice a day. As often as the forage in a corral was used up, the animals were moved to fresh grazing ground.

The sheep were kept in eight groups which received food as shown in Table I.

TABLE I.

GROUP I (5 yearlings)	GROUP II (5 yearlings)	GROUP III (5 yearlings)	GROUP VII (4 yearlings; 5 ewes; 5 lambs)
Received: alfalfa 4 pounds per head; salt; no fresh forage; no locoweed.	Received: alfalfa, 4 pounds per head; no salt; no fresh forage; no locoweed.	Received: alfalfa, 2 pounds per head; salt; no fresh forage; no locoweed.	Received: no alfalfa; salt; fresh forage and locoweed.
GROUP IV (5 yearlings)	GROUP V (5 yearlings)	GROUP VI (10 yearlings; 9 ewes and 8 lambs)	GROUP VIII (4 yearlings; 5 ewes; 5 lambs)
Received: alfalfa, 4 pounds per head; salt; fresh forage and locoweed.	Received: alfalfa 4 pounds per head; no salt; fresh forage and locoweed.	Received: alfalfa 2 pounds per head; salt; fresh forage and locoweed.	Received: no alfalfa; no salt; fresh forage and locoweed.

Groups I, II and III were kept in corrals in which there was nothing for them to eat except the alfalfa hay which was given to them daily. Groups IV, V and VI had the chance to eat locoweed and other growing plants in addition to the daily ration of alfalfa. Their corrals were moved as fast as the locoweed and other grasses were used up. Groups VII and VIII fed only on the locoweed and grasses to be found in the corrals. These corrals were constantly being moved so as to provide pasturage for their occupants. Groups I, III, IV, VI and VII received salt at frequent intervals.*

The animals were put in the corrals and the experiment started on July 15, 1904 and continued until September 6.†

The animals were closely watched to determine when they first began to eat the loco. On July 18 it was discovered that one ewe and one lamb in Corral VIII had been eating the weed and by evening a considerable quantity had been consumed. All the nutritious forage had been eaten out before the loco had been touched, and it was soon noticed that all the ewes, lambs and yearlings in corrals VII and VIII were eating the loco freely.

The sheep which received hay also, did not take to the loco so readily, and it was July 31 before there was any evidence that the animals in Corrals IV, V, VI were eating the weed. They did not begin to eat the locoweed until they had cleared out all the other green forage in the corrals. After they once began to eat the locoweed they showed quite a preference for it whenever they were subsequently placed in a fresh corral. However, they always ate abundantly of alfalfa, when it was furnished, and also of the other forage in the corrals, never confining their diet to the locoweed, even after they had formed the habit of eating it.

The experiment thus demonstrated perfectly clearly that sheep can be made to eat the locoweed, and that when they once begin eating it, they like it as much as other food, and possibly prefer it. It also appeared that sheep will not touch the weed while they receive a plentiful supply of green forage, but will take it if they are starved, or if they are fed on alfalfa hay and allowed to graze where locoweed is the only fresh plant.

* The assistance of Mr. Reese of the Montana Agricultural College, in caring for the animals, weighing them, moving corrals, etc., was of great value.

† While this experiment was in progress a second feeding experiment was conducted in a distant part of Montana. Five lambs and four ewes, all healthy animals were kept in corrals abounding with locoweed from June 10 to September 16. The experiment was conducted at White Sulphur, Montana, on the ranch of Mr. C. W. Cook from whom the sheep were obtained. The results agreed with those obtained at Ten Mile Flat, but it was impossible to give close continued attention to the animals, and the experiment is therefore not set forth in detail. No result was obtained which in any way conflicted with the results obtained at Ten Mile Flat.

The following field notes indicate the general condition of the animals:

August 7, 1904. Groups I and II. Sheep are not large, but are in fair flesh and appear healthy; one or two have cough, not very severe, with sneeze. If there is any difference between the groups it is hardly noticeable, possibly the unsalted sheep are slightly fatter than the salted. Quite a lot of hay is left on the ground. All fresh plants in corrals have been eaten.

Group III (½ alfalfa, no locoweed) can hardly be distinguished from Group I and II by their appearance. Sheep not quite so fat, but nearly so. Cough is, however, distinctly more pronounced. Not a wisp of hay left in the corral. Three of the five sheep sneeze, cough, and have nasal discharge. Flies seem to be troubling the noses of the sheep a good deal this morning.

Groups IV and V (alfalfa and locoweed). About as much hay left on ground as with I and II. No appreciable difference between the sheep of Group IV and those of Group V. About one-half the bunch have a cough and sneeze, etc., as with I, II and III. Locoweed and other grasses (except wire grass) have been completely eaten off. Animals look as well as or better than I and II.

Group VI (half rations plus locoweed). The yearlings, like those in the other groups, are undersized, and in this corral they are thin and scrawny, but not emaciated. The lambs (May lambs) are hardly one-half the size of June lambs recently seen in a healthy flock. The animals in Group I–VIII are suffering with the heat, and stand panting, with their heads together and near the ground, to avoid flies.

A small amount of alfalfa is still uneaten. The loco and grasses are being eaten. Certainly one-half the bunch have the cough, etc., as above described. Lamb No. 55 in corral VI has very severe cough, etc., and is distinctly weak; would be called a fairly severe "loco" by the average ranchman. Lamb No. 52 in corral VI seems weaker than No. 55, but does not cough, though his nose is filled with mucus. No. 52 and No. 55 do not run off with the rest of the bunch, but stay and let one come up to them. Every lamb in this corral has severe cough, eyes stuffed with mucus, except one larger and sturdier lamb.

Groups VII and VIII (sheep on loco without alfalfa). Sheep are poorer than the others; some are actually emaciated. Lambs even smaller than those in corral VI. No. 46 (lamb) has in addition to cough, etc., an open ulcer on left side of face opposite middle of cheek. In this corral the cough is found in nearly every animal, and is more severe than in the other corrals.

To generalize about the sheep. The day is very hot and the animals are sluggish, staying in groups with heads together or lying in corners and under the drinking troughs. None of the animals are what would be called first class sheep; all are small and scrubby. The yearlings are hardly larger than some lambs recently seen, and the lambs are not more than half size. The yearlings and lambs have grown extremely little. In each corral the animals are coughing, about one-half the animals in Group I, II and III being affected, more in Group IV and in the last two corrals pretty much every animal. In the last two corrals animals *seem about half starved* and the cough is much more severe. Several of the starved animals with this cough are what would be called "locoes" by ranchmen.

The cough, etc., affecting the sheep in Groups VI, VII and VIII became so severe that the animals began to die, and it looked as if the experiment

would be upset by this disease killing out the animals in the two most important loco pens—Groups VII and VIII. It was found necessary to build up the general health of the sick animals by abundant rations of alfalfa. This was continued for eight days, by which time the animals had improved sufficiently to allow the experiment to be resumed.

The following notes were made on August 18, the day after the experiment was resumed.

Groups I and II. All animals look well, no stiffness observed on motion; over half of them have occasional cough, and a little mucus from the nose; eyes are clear, and animals seem little troubled by cough.

The stiff stems of alfalfa have remained uneaten. Food given two and a half hours ago is eaten except for the stiff stems. Six sheep—some salted, some unsalted—are still eating. Very little difference apparent between salted and unsalted animals. Possibly unsalted are eating longer.

Group III. Animals are in fair trim, eyes clear, but all have cough and sneeze, which gives some distress. Almost every blade of hay given this morning is eaten, and all five animals are picking at what remains. No hay at all is left from yesterday.

Groups IV and V. Put in new corral of loco after 6 p.m. yesterday. This morning (8.30), in upper part of corral loco is eaten down, seed tops and leaves eaten, occasionally seed stalk left. In lower two-thirds of corral, loco still abundant.

These bands of sheep (IV and V) are the best looking of all, the sheep are in good flesh, eyes are bright; they are but little troubled by the cough, although most of them have it, and are the nimblest and most active of any band. Possibly, as with the sheep receiving full hay, the unsalted are a trifle fatter than the salted. One salted yearling wether is a trifle stiff and is more troubled by the cough than the others.

Group VI. So far as can be determined, the yearlings are as well off as those in pen No. III, both as regards general condition, flesh and cough. The ewes are a trifle thinner than the yearlings. The lambs are pretty badly off, Nos. 48 and 55 and another lamb are especially weakly, their noses stuffed up, eyes bleary and dull. All three lambs are undersized, weak and stiff in gait, and listless. Lamb No. 51 is twice as large as the others, seems better, but suffers more from cough than the yearlings. This lamb has all along eaten about double his share; another lamb is also large and in fairly good condition. Four of the seven lambs are hardly any larger than they were when received; the other three are undersized for their age but much better off than the smaller ones.

After feeding on full hay for eight days in order to relieve the cough, this bunch was turned into a new corral at 11 a.m. yesterday. The sheep had stopped picking the alfalfa which had been fed at 6 a.m. and a good deal still remained on the ground, the sheep being collected in groups with heads together. *When turned into the new corral, all animals at once began to graze eagerly, and continued for over an hour eating grass and loco as it was found.* The ewes and yearlings seemed to prefer the pods and the lambs ate only the leaves of the locoweed. This morning over nine-tenths of all loco is gone from the corral while not one-half of the grass seems to be gone. *Though careful observations were made yesterday and this morning, absolutely no effect could be seen in the sheep or lambs as the result of the weed, in spite of the fact that the*

animals have had more loco than they could eat, all at once, and after eight days of abstinence from the locoweed.

In addition to grazing, this band has eaten about all of the alfalfa this morning.

Groups VII and VIII. These sheep have improved greatly in the last eight days on their full hay ration. The ewes and yearlings are still the thinnest lot of all, but have improved greatly, being less suffocated, having less bloody mucus from nose, less cough and sneezing, and having gained distinctly in flesh. The animals are still more stuffed up than those in the other corrals. The lambs, without exception, are bunged up with rhinitis; eyes and face swollen, eyes and nose running, eyes dull, gait stiff and slow, most of them very weak and thin.

This band after eight days on hay, was turned into a new corral, about 10 a.m. yesterday, after they had stopped feeding on hay. *At once all began grazing, eating loco by preference, but also other grasses; ewes and yearlings eating the seed tops, lambs the leaves.* After one hour they stopped grazing until evening. *Absolutely no effect could be noted in any sheep as the effect of eating the plant.*

This morning not one loco plant can be found, and in several cases the ewes and yearlings have been seen digging at the root, but apparently they have not eaten the plant below the surface of the ground. The corral still contains about one-quarter to one-third of the grasses and other plants.

The facts of special interest that the experiment afforded up to this time were, that the animals were eating the locoweed, that their general condition was pretty poor, that many of them suffered from cough and rhinitis and that some of the animals with cough would pass as locoed animals with more than half the ranchers. The condition was studied, and the diagnosis was made that the animal was suffering from the sheep fly disease, a diagnosis which was confirmed by autopsy. It was noticed particularly that this disease affected animals in every one of the corrals, those receiving no loco as well as those receiving loco. It was also noticed that the animals receiving the greatest amount of food suffered less severely than animals on insufficient rations; thus the animals receiving four pounds a day of alfalfa and allowed to graze freely on loco stayed in the best condition, the animals receiving four pounds a day of alfalfa alone did almost as well. The animals receiving half rations of alfalfa either with or without loco were more severely diseased. The animals receiving no alfalfa, but scraping a bare subsistence by grazing on the insufficient forage and loco, were the ones most severely diseased. No difference could be seen in the animals receiving salt and in those receiving no salt, as far as this disease was concerned. So severe was the outbreak of sheep fly disease, that the experiment was discontinued for eight days, as noted above, and the animals were kept in their corrals and fed abundantly with alfalfa hay. The symptoms promptly abated, and the experiment was resumed.

It is interesting to note that up to the time of interrupting the experiment, certain groups of animals had been receiving an abundance of loco-

weed without manifesting any symptoms that could be attributed to the action of the weed.

When the experiment was interrupted, it might have been expected that the animals would show symptoms from being suddenly deprived of the weed, just as morphine habitues, alcoholics and tobacco smokers show symptoms when suddenly deprived of their drugs. This did not occur with the sheep, and they were carefully watched in order to observe any manifestations of this nature. On the contrary, the improvement in the condition of the sheep when their diet was increased was almost immediate and resembled nothing so much as the improvement which takes place in a half starved animal when it is placed upon a proper diet.

When the experiment was resumed, another interesting observation was made: The animals were turned back upon the abundant loco fields after an abstinence from the weed lasting for eight days. It is a common impression that drug users exhibit symptoms when they are suddenly put upon full doses of their drugs after abstinence. This did not occur with the sheep. They were turned into the corrals with loco about an hour after they had finished eating the alfalfa hay which had been given them. They had left some alfalfa hay uneaten, and were lying around in the corners of the corrals. When turned into the corral with fresh forage, they at once began to graze, eating loco and other plants for an hour and a half. At no time did any animal exhibit a single symptom that could be attributed to the weed.

Another very interesting observation was made during this infection with the sheep fly. The animals badly infected with these parasites presented the most typical pictures of loco disease. On turning to the description of sheep fly disease, the Western rancher might well think that the writer of the book was confused and was writing a description of the locoweed disease. It must be remembered, however, that sheep fly disease occurs all over the world, and the symptoms have been described as characteristic for animals which are entirely beyond the reach of locoweed.

The following description taken from Neumann's *Parasites and Parasitic Diseases of the Domesticated Animals*, 1903, pp. 568–570, is inserted in order to make this clear:

"It (the sheep fly) hides in holes and crevices in the walls of the sheepfolds, which it leaves when coupling time has arrived and the temperature is sufficiently high. It then flies in a lively manner to greater elevations, and rests on rocks warmed by the sun. The fecundated female now goes in search of flocks of sheep, which are afraid of its approach, and to avoid it lie down, bury their noses in the dust between their forefeet, or are huddled together with their heads down. According to Bracy-Clark,

they raise clouds of dust to deceive their enemy. It is during rumination that the insect finds a particularly favorable time for depositing its progeny. Its small size, gray color, and the rapidity of its flight, do not allow its ovulation to be observed; but there can be no doubt that it does not take place on the nose of the sheep. As soon, in fact, as these animals have been touched by the Oestrus, they become excited, run in every direction, hold down their noses and rub them against the ground or against their feet; often look anxiously around them, sneeze and snort, and seek ditches, furrows and dusty roads. Owing to the repeated rubbings, the nostrils are often abraided and inflamed. . . . . *Symptoms.*—It is usual to find three or four larvae of the Oestrus in the frontal sinuses of sheep, which, during life, had not given any indication of their presence. They rarely occasion any morbid disturbance, unless they are numerous and advanced in development at the commencement of spring. The first sign of their presence is a discharge, often unilateral, at first clear and serous, then thick and mucus, from the nostrils. Then there are frequent sneezings and snortings, accompanied by the expulsion of the mucus, and sometimes of the larvae. Later the animals throw the head upwards, often shake it, rub the nose on the ground, against some part of the body within reach, or with the forefeet. As the malady progresses the sheep hold their heads low, lift their limbs high in movement, as if walking in water—their gait resembling that of horses affected with immobilitie. Sometimes they suddenly throw up the head, carry the nose high, then move it convulsively. From time to time they stagger and are attacked with vertigo, but they do not turn in a circle. In more serious cases there is dyspnoea, the upper air-passage being obstructed by the larvae or the inflammation of the pituitary membrane. The eyes are red and lachrymose. The disease may be more complicated, the animals losing their appetite and their condition; they grind their teeth; foamy saliva flows from their mouth; the eyes pirouette in their orbits; and convulsions set in, then death ensues, sometimes in six to eight days after the appearance of the first symptoms. . . . . The common saying that a whimsical person is 'maggoty,' or has got 'maggots in the head,' perhaps arose from the freaks of sheep affected by these larvae.

"But it is rare that the malady reaches this paroxysm; it continues for a long time, and generally—the larvae being ejected one after another—the symptoms gradually subside, until they disappear altogether."

On September 6 the experiment was closed having lasted fifty-three days. The animals at that time had eaten bare a wide patch of loco. The total area covered by the sheep feeding on loco was: Groups IV and V, 57,894 square feet; Group VI, 289,854 square feet; Groups VII and VIII, 387,084 square feet. The corrals varied from 16,000 to 48,000 square feet in size.

The animals did not thrive on Ten Mile Flat, and did not do nearly so well as the original band (3,200), from which the animals were selected for experiment and which were kept on the mountain side where the forage was fairly abundant, and living conditions better. Even in this band, however, there were one or two hundred animals undersized, stiff-legged and evidently suffering from sheep fly disease.

The following tables show the weights in pounds of the animals when the experiment was begun and the weights at the close of the experiment or at the death of an animal, with the average change in weight for each group.

Group I, receiving daily 4 pounds of alfalfa per head and salted regularly.

TABLE II.

TAG NO.*	INITIAL WEIGHT	FINAL WEIGHT	ALTERATION IN WEIGHT	REMARKS
	pounds	*pounds*	*pounds*	
14	68	71	+ 3	All of group were yearlings.
31	70	74	+ 4	
4	58	59	+ 1	
5	61	73	+ 12	
10	73	73	+ 0	
Total.....	330	350	+ 20	Average increase 6.06 per cent.

* Each animal was numbered with an ear tag.

Group II, receiving daily 4 pounds of alfalfa per head, but no salt.

TABLE III.

TAG NO.	INITIAL WEIGHT	FINAL WEIGHT	ALTERATION IN WEIGHT	REMARKS
	pounds	*pounds*	*pounds*	
6	68	72	+ 4	All of group were yearlings.
34	74	81	+ 7	
24	61	58	− 3	
33	72	84	+ 12	
43	77	81	+ 4	
Total.....	352	376	+ 24	Average increase 6.81 per cent.

Group III, receiving daily 2 pounds of alfalfa per head, and salted regularly.

TABLE IV.

TAG NO.	INITIAL WEIGHT	FINAL WEIGHT	ALTERATION IN WEIGHT	REMARKS
	pounds	*pounds*	*pounds*	
15	66	68	+ 2	All of group were yearlings.
37	66	72	+ 6	
40	67	71	+ 4	
18	74	73	− 1	
36	77	81	+ 4	
Total.....	350	365	+ 15	Average increase 4.28 per cent.

Group IV receiving daily 4 pounds of alfalfa per head, salt and locoweed.

TABLE V.

TAG NO.	INITIAL WEIGHT	FINAL WEIGHT	ALTERATION IN WEIGHT	REMARKS
	pounds	*pounds*	*pounds*	
2	67	73	+ 6	All of group were yearlings.
21	60	71	+ 11	
41	78	83	+ 5	
12	62	70	+ 8	
42	62	68	+ 6	
Total.....	329	365	+ 36	Average increase 10.94 per cent.

Group V, receiving daily 4 pounds of alfalfa per head, locoweed, etc., but no salt.

TABLE VI.

TAG NO.	INITIAL WEIGHT	FINAL WEIGHT	ALTERATION IN WEIGHT	REMARKS
	pounds	*pounds*	*pounds*	
17	70	77	+ 7	All of group were yearlings.
29	73	83	+ 10	
23	73	85	+ 12	
1	70	80	+ 10	
32	57	69	+ 12	
Total.....	343	394	+ 51	Average increase 14.86 per cent.

Group VI, receiving daily 2 pounds of alfalfa per head; salted regularly, locoweed.

TABLE VII

A, yearlings

TAG NO.	INITIAL WEIGHT	FINAL WEIGHT	ALTERATION IN WEIGHT	REMARKS
	pounds	*pounds*	*pounds*	
11	76	89	+ 13	
35	77	84	+ 7	
38	73	76	+ 3	
19	68	61	− 7	
9	75	80	+ 5	
3	60	64	+ 4	
8	68	73	+ 5	
26	76	80	+ 4	
16	75	79	+ 4	
27	71	67	− 4	
Total.....	719	753	+ 34	Average increase 4.72 per cent.

TABLE VII—Continued

B, ewes

TAG NO.	INITIAL WEIGHT	FINAL WEIGHT	ALTERATION IN WEIGHT	REMARKS
70	93	86	− 7	
71	84	97	+ 13	
84	74	78	+ 4	
80	71	81	+ 10	
73	82	80	− 2	
76	98	105	+ 7	
75	77	78	+ 1	
78	68	80	+ 12	
67	79	81	+ 2	
Total.....	726	766	+ 40	Average increase 5.5 per cent.

C, lambs

48	25	20	− 5	Died August 26.
51	27	32	+ 5	
52	22	18	− 4	Died August 7.
53	24	26	+ 2	Killed September 1.
55	17	20	+ 3	Killed September 1.
61	30	29½	− ½	
62	21	21½	+ ½	
63	30	37	+ 7	
Total.....	196	204	+ 8	Average increase 4.08 per cent.

Total initial weight of Group VI.....1641 pounds
Total final weight of Group VI.....1723 pounds
Total alteration in weight Group VI..... 82 pounds increase
Average increase in weight, Group VI.....4.99 per cent increase

Group VII, receiving no alfalfa; salted regularly; fed on locoweed.

TABLE VIII

A, yearlings

TAG NO.	INITIAL WEIGHT	FINAL WEIGHT	ALTERATION IN WEIGHT	REMARKS
	pounds	*pounds*	*pounds*	
39	76	74	− 2	
25	(72)			Killed August 23. No weight taken.
20	66	69	+ 3	
22	74	70	− 4	Died September 9.
Total.....	216	213	− 3	Average loss 1.39 per cent.

TABLE VIII—Continued

B, ewes

TAG NO.	INITIAL WEIGHT	FINAL WEIGHT	ALTERATION IN WEIGHT	REMARKS
74	79	79	0	
69	108	97	− 11	
68	74	72	− 2	
66	110	102	− 8	
72	78	77	− 1	
Total.....	449	427	− 22	Average loss 4.9 per cent.

C, lambs

59	22	23	+ 1	Died September 6, weight of 20 pounds.
46	41	37	− 4	Died August 29.
49	30	31	+ 1	
56	31	32	+ 1	
58	25	23	− 2	Killed August 19.
Total.....	149	146	− 3	Average loss 2.01 per cent.

Total initial weight of all animals in Group VII (excluding No. 25)..... 814 pounds
Total final weight of all animals in Group VII (excluding No. 25)..... 786 pounds
Total loss of weight of all animals in Group VII..... 28 pounds
Average alteration of all animals in Group VII.....3.43 per cent decrease

Group VIII, receiving no alfalfa and no salt; fed on locoweed, etc.

TABLE IX

A, yearlings

TAG NO.	INITIAL WEIGHT	FINAL WEIGHT	ALTERATION IN WEIGHT	REMARKS
	pounds	*pounds*	*pounds*	
13	77	78	+ 1	
30	74	72	− 2	
28	71	70	− 1	
7	70	71	+ 1	
Total.....	292	291	− 1	Average loss 0.34 per cent.

TABLE IX—Continued

B, ewes

TAG NO.	INITIAL WEIGHT	FINAL WEIGHT	ALTERATION IN WEIGHT	REMARKS
81	72	70	− 2	
82	(76)			Died. Weight not recorded.
77	69	64	− 5	
79	74	84	+ 10	
83	72	79	+ 7	
Total.....	287	297	+ 10	Average gain 3.48 per cent

C, lambs

57	37	37	0	
47	22	15	− 7	Died August 21.
54	31	34	+ 3	
60	30	33	+ 3	
50	29	22	− 7	Died August 29.
Total.....	149	141	− 8	Average loss 5.67 per cent.

Total initial weight of Group VIII (excluding No. 82)..... 728 pounds
Total final weight of Group VIII (excluding No. 82)..... 729 pounds
Total alteration in weight of Group VIII..... 1 pound gain
Average alteration in weight of Group VIII.....0.0137 per cent increase

A study of these tables corroborates the general impressions derived from daily inspections of the experimental animals, and justifies the following conclusions.

1. The animals were not particularly large, the gains in weight were small even at the best.

2. The animals which increased most in weight were those in Groups IV and V (receiving alfalfa and locoweed, Tables V and VI), their gains being far ahead of those made by any other animals used in the experiment. The animals in Groups I and II (Tables II and III, alfalfa but no locoweed), came next, but they did not gain nearly so much. The animals in Group III (Table IV, one-half alfalfa, no loco) and Group VI (Table VII, one-half alfalfa, and locoweed) were third, with gains which were nearly the same in each group. As might be expected, groups VII and VIII (Tables VIII and IX, no alfalfa, all locoweed), made the worst showing, and presented a total actual loss of weight.

3. The animals receiving half rations of alfalfa, and locoweed (Table VII—A, Group VI) throve better than those on half rations not eating locoweed (Group III, Table IV).

4. The gains in weight were directly proportional to the actual amount of food and also to the amount of fresh forage obtained by the sheep.

5. The animals which throve best were eating abundantly of locoweed, in addition to having an abundance of alfalfa hay together with the rather scanty natural forage of growing plants other than locoweed.

6. Animals receiving no salt (Group II, Table III and Group V, Table VI), gained more in weight than the animals receiving salt (Groups I and IV). The unsalted animals on locoweed alone (Group VIII, Table IX) gained 1 lb., while the salted animals on loco alone (Group VII) lost 28 lbs. It is remarkable that the lambs on locoweed with no salt (Table IX, C) lost more weight than the lambs on locoweed with salt, (Table VIII, C) while with the yearlings on locoweed (Tables IX, A and Table VIII, A), and especially with the ewes (Tables IX, B and VIII, B), the unsalted were better off. Although slightly heavier, the unsalted animals were not more resistant to the sheep fly disease.

7. In general, the larger and stronger animals did better in each corral than the younger and weaker ones; (seen by comparing the average alteration in weight of the ewes, yearlings and lambs, respectively, in Groups VII and VIII, and remembering that the greatest relative increase should be found in growing lambs).

8. The tables show clearly that when enough nutritious food is provided, the locoweed (*A. spicatus*) certainly does not injure the health of sheep, within the limits of time taken for this experiment.

In addition to the inductions just drawn from the tables, the general conclusions from the experiment may be stated in brief;

1. Healthy sheep appear not to eat locoweed if they can easily obtain a plentiful supply of green forage.

2. Sheep can easily be made to eat locoweed by depriving them of other food; by diminishing other food; or by diminishing other green forage available, even though the animals be well fed on alfalfa.

3. Animals which have started to eat locoweed, do not eat it to the exclusion of other food, although they do appear to eat rather more of locoweed than of any other single plant. The lambs eat the leaves, the yearlings and adult sheep eat the stalks and pods. Once in a while an adult sheep will be found rubbing with his forefeet for the root of the weed, but this was rare. The usual cause for sheep rubbing the nose in the ground is the presence of sheep fly larvae in the nose.

4. There was no evidence that the locoweed produced any poisonous effect, clinical or anatomical, in a single sheep during the fifty-three days of this experiment. The evidence indicates that the food value of the weed must be very slight, but if the plant has any narcotic or other action, it is so obscure that it could not be made out by careful and frequent observations of the animals used for this experiment. It is to be noted again that no symptoms developed when the sheep eating the plant were suddenly deprived of it, nor when they were returned to it after a week's abstinence; and that sheep on abundant locoweed and abundant other food were the ones which throve better than any others in this experiment.

5. The sheep used in this experiment did not thrive. This applies to the sheep receiving alfalfa only, as well as to those receiving loco. At the beginning of the experiment the sheep and lambs were average healthy specimens. At the end of the experiment the animals had either gained very little or had lost weight and were evidently in much poorer shape than the members of the flock from which they were selected and which had been kept on the mountain side. The causes for the failure of these sheep to do well were probably confinement, lack of protection against the intense heat of the sun, insufficient green forage, and inadequacy of food in the case of those not receiving alfalfa.

6. During the course of the experiment, sheep fly disease broke out among the animals, giving every appearance popularly attributed to loco disease, and affecting indifferently those eating locoweed and those not eating it. The animals most severely diseased were those receiving the least food.

7. The vermifuges used before starting the experiment did not remove the *Thysanosoma actinioides*.

8. In the course of this rather short experiment, no ill effects were observed in animals deprived of salt.

Soon after concluding the feeding experiment at Ten Mile Flat, the sheep which remained were sent to the Montana Agricultural College where interesting studies were made to determine whether they could be profitably fattened for market. The report of the experiment has been published by Linfield (Bull. No. 59, Montana Agricult. Exp. Sta., 1905). He found that the sheep gained only about half as fast as healthy sheep, and that it was unprofitable to prepare them for market on account of the length of time and cost of the feed required to fatten them.

From time to time during the experiment, a yearling or a lamb died, or was killed, and examined at autopsy. The sheep fly larvae were found in great abundance wandering over the nasal passages and up into the cavi-

ties of the head; bronchopneumonia and parasitic worms were also found. A few typical autopsies are detailed below, and the others are summarized.

Autopsy 16. Lamb No. 52, from Corral VI, May lamb of Van Cleve's flock, weight 18 pounds, length 28½ inches from tip of nose to root of tail. Lamb had been in poor condition for some time, suffering with cough, like the rest of the flock, frequently digging its nose into the ground, and occasionally raising its head high in the air. The animal was very weak, walked feebly, ran behind the rest of the bunch of sheep, raising its legs, especially the hind legs, as if wading through water. On August 6 the animal looked very ill, the cough and running from the eyes being very pronounced, the face being swollen and the animal very weak. The lamb died on the evening of August 7 and was autopsied at 9.30 a.m., August 8.

Anatomical diagnosis. Acute bronchopneumonia right and left lungs, with abscess formation, empyema, and bronchitis; acute intense inflammation of mucous membranes of nasal passages and superior orbital sinuses; twenty to forty embryos of *Oestrus ovis* crawling in sinuses, nares and trachea. Emaciation. Adhesions between omentum, ventral wall, intestines and stomach with cysts in the midst of the adhesions containing caseous-purulent contents (*Cysticercus tenuicollis?*); openings from the paunch into four of above-mentioned cysts. Sarcosporidiosis. Irregular incisor teeth.

The lamb was undersized with practically no subcutaneous fat, muscle reddish brown, clear and translucent. Several lymph glands in the femoral region were found large, red and soft; on section being much injected, and having dilated capillaries. The abdominal wall was tightly adherent to the omentum by fibrous adhesions which also bound the omentum to the paunch and intestines. In the adhesions were twenty or thirty small cysts about 1 x ½ cm. with walls approximately 1 or 2 mm. thick. These cysts were smooth on the inside but exteriorly were bound in fibrous tissue. One cyst contained a formless mass of semi-caseous, yellow, purulent material. The cysts were distributed on the under surface of the diaphragm, over the paunch, in the loops of the gut and in the pelvis. The omentum and mesentery were devoid of fat. Mesenteric and retroperitoneal lymph glands large and soft, the retroperitoneal lymph glands were numerous, varying in size from a pin's head to 3 mm. in diameter. The intestines were clear throughout, the stomach contained a moderate amount of soft food. In the first stomach opposite the transverse furrow were three or four round openings 4 or 5 mm. in diameter extending through the stomach wall and communicating directly with the cavity of the caseous cyst described above, pressure upon the cysts forcing pus through the stomach openings.

Spleen 10 x 6½ x 2 cm., small, soft, no adhesions. On section very soft, structures not visible. Liver of fair size, surface smooth. The gall bladder and bile ducts were clear. Kidneys; capsule stripped readily, leaving pale mottled surface with the cortex averaging 11 mm. On section the kidney was gray, and cloudy, the glomeruli were seen indistinctly, the striations easily visible. The pelvic organs and adrenals were normal, the pancreas was soft and showed post-mortem changes.

Thorax. The left lung was tightly bound by fibrous adhesions to the chest wall, the apex and dorsal surface of the lung being free, the rest of it being bound to the chest wall, to the pericardium and the diaphragm. In freeing the lung a cavity was opened into in the lower left lobe and about 100 cc. of thick yellowish gray pus escaped. The entire lung was consolidated except the apex and upper dorsal part of upper lobe.

The cavity occupied two-thirds of the lower lobe on the ventral and inferior sides. On section the cavity had smooth lining and contained pus and semi-caseous yellowish material. The consolidated lung was of a dark red color, not crepitant, rather dry with very little excess of mucus in the bronchi. The bronchi were injected, the bronchial lymph glands greatly enlarged, red and soft. The right lung was also adherent to the diaphragm and pericardium and to the ventral surface of chest wall. There were several abscesses varying from 5 to 8 cm. in diameter in the lower lobe, the consolidated portions resembling the left lung.

Heart. The pericardial and epicardial fat was absent. The surfaces were smooth and glistening. On the anterior (ventral) surface were a few ecchymoses. The valves were clear and delicate, the endocardium clear, the myocardium pale grayish brown, opaque. Just below the larnyx several Oestrus larvae were found crawling around the trachea, which was markedly injected. The mouth was clear, the incisor teeth were loose and twice as long as normal. Nares. The nose was covered with mud. On longitudinal section of the head the mucous membrane over the turbinated bones, septum, etc., was intensely engorged, dark red in color, ecchymotic and covered with thick muco-pus. Great numbers of small Oestrus larvae were found crawling over the mucous membranes as high as the ethmoidal turbinates. Brain and spinal cord presented no abnormality.

Microscopic report. The heart cells were granular, the cross striations not distinct. No sarcocysts were found. Lung. Sections from several parts of lungs showed areas of bronchopneumonia with abscess formation. The pleura was considerably thickened, showing granulation tissue together with large pink mononucleated cells, lymphocytes and polymorphonuclear leukocytes. In a section through the edge of an abscess, the necrotic tissue in the center presented the appearance of a homogeneous débris; passing out from the center there were zones of inflammation becoming less intense to almost normal lung tissue. In the zones of inflammation the predominating cells were large, mononucleated cells with bright pink granular cytoplasm, together with numerous lymphocytes and polymorphonuclear leukocytes. The distribution of the exudate in the lung alveoli was irregular, some alveoli being plugged with exudate, others empty. Desquamated cells and débris appeared in the lumina of the bronchi. Spleen, capsule not thickened, malpighian bodies visible but not conspicuous, showing evidence of hyperplasia in the centers; the pulp congested, it being difficult to distinguish sinuses from pulp. In the pulp were found many red cells and fragments of red cells together with large endothelioid cells which frequently were more or less tinged with blood pigment. A few cells resembling nucleated reds but not positively identifiable were seen in the pulp. Liver, the cells and cell columns were separated, the cells being swollen and vacuolated as if from post-mortem change. Kidney, the epithelium lining the tubules was extremely granular, cloudy and rather vacuolated. Lymph gland, capsule appeared rather edematous, the peripheral sinus only faintly seen. Cell nests not separated from cell columns. The striking feature of the lymph gland was that the periphery of the gland was densely packed with lymphoid cells while the central portions were especially marked by dilated sinuses partly filled with what appeared to be free cells. The cells in the peripheral region varied from small lymphoid cells to large mononuclears, the former predominating. Some of the larger cells had a bright pink non-granular cytoplasm. The dilated sinuses were moderately well filled with large desquamated endothelial cells with vacuolated or pink cytoplasm together with fairly abundant

lymphoid cells. The desquamated endothelial cells dominated the appearance in the sinuses. The blood vessels of the lymph gland were markedly congested.

Voluntary muscle. Poorly preserved, showed small bodies which were not very distinct but appeared to be sarcosporidia.

Section through abscess cyst of omentum. Cyst was about 1 cm. x ½. Capsule thin, the outer part being made of laminated connective tissue, the inner portion of young granulation tissue in which there were great numbers of cells resembling large mononuclear leukocytes, and a number of small mononuclears, together with many rather granular and swollen cells of fibroblastic appearance. The inner edge of the wall passed off suddenly into a region of coagulation necrosis in which were found fragmenting nuclei, polymorphonuclear leukocytes and purple débris. This was continuous with a pinkish granular débris filling the center of the cavity. There was no evidence of daughter tubercle formation in the wall of the cyst but the general appearance suggested tuberculosis as a possible diagnosis.

Autopsy 17. Lamb 58, from Corral VII (no alfalfa), had become very ill but had improved markedly when fed on alfalfa, when the experiment was interrupted, and had remained fairly well after being returned to the loco diet; was removed from the corral for the examination. The temperature of the lamb was 101 (rectal temperature); the lamb was emaciated and stiff-legged but was not one of the illest lambs in the corral. It coughed a good deal but seemed in better condition than it had been previous to the diet of alfalfa hay. Its weight was twenty-three pounds. The animal was chloroformed and autopsied at once on August 19.

Anatomical diagnosis. Oestrus ovis infection of nasal passages with muco-purulent inflammation. Multiple pin head bronchopneumonic patches in both lungs. Emaciation. Infarction in liver; *Thysanosoma actinioides* hepatitis. Irregular incisor teeth.

The skin, muscles, and peritoneal cavity were clear; there was a small amount of fat. The spleen was small, soft, translucent, the structures appearing normal. The liver was smooth, semi-translucent excepting for an irregular wedge-shaped area on the upper surface on the left lobe just to the left of midline. This area was not raised, was smooth and had a mottled, grayish red color with fine, pin point dark mottlings. On section the area was wedge-shaped extending 1½ cm. into the liver. The kidneys, pancreas, and bile ducts, stomachs, pelvic viscera, and adrenals presented no abnormality. One small, fringed tapeworm found in the intestines. Heart contained a fair amount of fat; was clear throughout except that muscle was rather gray and opaque.

The lungs were voluminous, surface smooth, for the most part pink, but mottled at irregular intervals with dark red points varying from a pin head to 1 cm. in size. On section the dotted appearance was also seen as if from very numerous, small areas of consolidation. There were no tubercles and no cavities found. The right and left lung were alike. The bronchi and trachea contained frothy, blood-tinged mucus. The turbinated passages were swollen, dark red and covered with muco-pus. A large Oestrus larvae and six small ones were found in the nasal passages. The incisor teeth were unusually long.

Microscopic report. Heart striations and fibrillations distinct, often the clear space around the heart nucleus seemed rather larger than usual. No other noticeable alteration. Lung, showed small regions in which the alveoli were packed with red cells and coagulated albumin, alternating with relatively normal lung. In the region

with exudate there were remarkably few leukocytes and only a few desquamated epithelial cells. No fibrin was made out in the H. and E. specimen. The bronchi were practically clear. The alveolar capillaries in general congested. Spleen, malpighian bodies conspicuous, rather dense, and larger than usual, apparently however, a normal spleen.

Liver. A small block showed considerable thickening throughout the portal systems, chiefly around the bile ducts with rather edematous tissue. The central third of the section was devoid of liver tissue and showed a mass of cellular material with two or three areas of necrosis. In this tissue were dilated bile ducts. The cellular tissue was composed of fibroblasts of various size, many of which contained a slight amount of brownish pigment. Among them were mononuclears, polymorphonuclears and eosinophiles. The eosinophiles were abundant and in part appeared to have polymorphous nuclei, in other less frequent instances, single, round nuclei. Compressed and degenerating liver tissue was found at the edge of this cellular accumulation and evidence of the extension into the liver of the newly forming connective tissue was met with. At the edge of the connective tissue there was hemorrhage into the liver. Elsewhere the liver cells were cloudy, vacuolated and granular.

Kidney showed a moderate amount of coagulated albumin in the tubules. The convoluted tubular epithelium moderately cloudy, otherwise the kidney appeared normal. Mucosa of nares; the most striking feature was the very great dilatation of the blood sinuses and bood vessels, the intervening tissue being distinctly edematous. In the edematous tissue were found numerous eosinophiles with polymorphous nuclei, large mononuclears and a few lymphocytes. The eosinophile was the most striking and probably the most abundant infiltrating cell. The epithelium of the glands was very cloudy and full of mucus. Immediately beneath the surface epithelium there were rather dense accumulations of mononuclears, chiefly lymphocytes, the eosinophiles being less abundant in this region. Section of lymph gland, showed widely dilated central sinuses with phagocytic endothelial cells. Voluntary muscle appeared clear, no sarcocysts being found. Epithelium and wall of esophagus appeared normal.

Autopsy 18. Lamb 47 from Corral VIII. The lamb had been very feeble but had improved during the week of alfalfa feedings. Subsequently it fell into worse condition and died on the evening of August 21. The autopsy was performed at 2 p.m., August 22.

Anatomical diagnosis. Oestrus ovis infection; acute mucopurulent inflammation of mucous membrane lining the nasal passages and accessory sinuses; bronchopneumonia with abscess formation. Infection with *Thysanosoma actinioïdes.* Irregular incisor teeth.

The animal weighed 15 pounds, its wool was ragged, incisor teeth loose and long. Emaciation was extreme. The peritoneal cavity was clear, there was no fat visible, the mesenteric glands were large, pale and soft.

The liver, spleen and kidneys appeared normal. A small fringed tapeworm was found in the small intestine. The stomachs appeared normal. Both lungs were adherent over the ventral and cephalad portions by fibrous adhesions, denser on the right side. In each lung were multiple small areas of consolidation with abscess formation. The bronchi contained bloody mucus. Heart appeared normal, except for absence of fat. On opening the head the engorgement of the mucous membrane of the nasal passages was intense, there being many larvae crawling over the mucous membrane with muco-pus and pin point hemorrhages into the mucosa.

Microscopic report. Heart muscle cloudy, striations indistinct, fibrillations still well marked.

Lung, showed bronchopneumonia, many of the alveoli being packed with a cellular exudate, while adjacent alveoli were relatively free or showed only coagulated albumin and desquamated epithelium. The exudate consisted of desquamated epithelium, coagulated albumin and great numbers of polymorphonuclear cells. In one or two of the alveoli elongated cells were met with of a fibroblast appearance but new capillaries could not be seen. Section did not pass through one of the abscesses. Spleen, capsule not thickened, malpighian bodies not very sharply marked but could be seen. Pulp cellular, the sinuses not being distinct. Liver cells rather large and cloudy, being separated as if there was slight post mortem change, otherwise liver seemed normal. Kidney, normal except for quite marked post mortem change affecting the convoluted tubules. Parotid gland markedly congested, the acini being made up of large purple mucus-containing cells which were not very well preserved. No abnormality could be made out. Lymph gland presented much the features described in previous autopsies, the periphery being packed with lymphoid cells, the blood vessels intensely congested, the central sinuses widely dilated and containing moderate numbers of free cells. Section through esophagus showed normal epithelium and normal muscle wall. Section through vomer showed markedly dilated blood vessels in the mucosa, with advanced mucoid change in the glands. There was also edema of the tissue between the glands. Rather numerous and small lymphoid cells were distributed throughout the mucosa. Section through turbinated bone; the high columnar mucosa was fairly well preserved, beneath which came a markedly edematous tissue containing greatly dilated blood vessels, eosinophiles, lymphoid cells and large mononuclears. Sections through several regions of the nasal mucosa showed similar conditions. In some regions the exudate was slightly more abundant than in others, but the same general features prevailed. The glands in this tissue usually contained a purplish material apparently mucus, sometimes a coagulated pinkish material like albumin.

Autopsy 19. One of the yearlings from Corral VIII had looked rather ill for some time but evidently was convalescing after the use of the alfalfa hay. The animal was still coughing and sneezing; walked stiffly and had a bloody discharge from the nose. On August 23, the animal was chloroformed and autopsied at once.

Anatomical diagnosis. Oestrus ovis infection, subacute. *Ostertagia marshalli* in stomach; *Thysanosoma actinioides* in bile ducts, hepatitis, emaciation. Sarcosporidiosis.

Autopsy 22. Lamb No. 48 was brought from Corral VI, in dying condition. It was seen living on the morning of August 26, but was dead at 2 p.m. and was autopsied at once.

Anatomical diagnosis. Acute *Oestrus ovis* infection. Acute bronchopneumonia. Emaciation.

Autopsy 25. After two months of drouth a heavy cold rain fell on the evening of August 28. On the following morning lambs 46 from group VII, and 50 from group VIII, were dead. Lamb 46 had always been a heavy feeder and looked like one of the strongest in the pen. Autopsy, 8.15 a.m.

Anatomical diagnosis. Acute bronchopneumonia. Acute splenic tumor. Cloudy swelling of myocardium, liver and kidney. Acute catarrhal enteritis of lower ileum and cecum. Acute mucopurulent rhinitis and sinusitis with about a dozen young

Oestrus larvae and one or two older ones in the supraorbital sinus. *Cysticercus tenuicollis* in peritoneal cavity. Sarcosporidiosis. Acute lymphadenitis. Brain and spinal cord normal.

Autopsy 26. Lamb 50, Corral VIII, found dead on morning of August 29, after a cold rain during the previous night.

Anatomical diagnosis. Acute bronchopneumonia. Acute *Oestrus ovis* rhinitis, emaciation. Irregular incisor teeth. Brain normal.

Autopsy No. 30. Lamb No. 55, from Corral VI, was much stunted and emaciated. Fleece was fairly regular and thick. The animal was very weak and uncertain on its feet and walked with a stiff-legged gait. There was marked coughing and sneezing. The respirations were difficult, irregular with many pauses and many short, broken, inspirations. Taking the average of five minutes' count there were 100 respirations per minute. The rectal temperature was 102°. The eyes were gummed with mucus. The eyelids puffy and swollen. The nose was covered with muco-pus and dirt. The lamb was so weak that it could hardly get to its feet when it had been laid on the ground. September 1, 1904, animal was bled to death and autopsied at once.

Anatomical diagnosis. Subacute (convalescent) Oestrus rhinitis and sinusitis with empyema of ethmoidal sinus, cervical lymphadenitis. Bronchopneumonia. Emaciation. Irregular incisor teeth. Red marrow. Brain and spinal cord normal.

Lamb 53, from Corral VI, was selected for examination on September 1. The hemogoblin was 70 per cent (Tallquist), the weight 26 pounds. The lamb was kept till September 5 on alfalfa hay when the weight was 28½ pounds. Respirations were irregular, 46 to the minute, temperature 102°. The paunch of the lamb was distinctly distended; the animal was very weak and thin. When laid on the ground it could hardly recover its feet. It walked with an uncertain stiff-legged gait. The animal at time of examination on September 5 was in better condition than it was a week earlier and for the last four days, between September 1 and 5 improved steadily upon a hay diet. The animal had good vision, it recognized a person bringing alfalfa or water to it. There was no evidence of psychic disturbance. The animal's breathing was distinctly impaired, especially at night and during early morning hours. In the morning, especially, the head was stuffed up, the eyelids being gummed together and there being a discharge from the nose of thick mucus. The animal was bled to death on September 5 and autopsied at once.

Autopsy 31. September 5, 904.

Anatomical diagnosis. Subsiding Oestrus rhinitis and sinusitis; empyema of ethmoidal cells; bronchopneumonia; *Thysanosoma actinioides* dilating common duct, cystic duct and beginning to enter liver ducts; *Cysticercus tenuicollis*; emaciation. Irregular incisor teeth. Brain and cord, and stomachs and intestines normal.

Lamb No. 59 from corral VII was found dying on morning of September 6. Died about 11 a.m. Autopsy at 1.30 p.m.

Autopsy 32. Anatomical diagnosis. Bronchopneumonia, serofibrinous pleurisy on right and left; small purulent cysts in lungs. *Oestrus ovis* in nasal cavities; empyema of ethmoidal turbinatea; *Thysanosoma actinioides;* emaciation. Acute splenic tumor. Necrosis in lymph gland.

D. DISCUSSION OF PARASITIC DISEASES ENCOUNTERED.

During the summers of 1903 and 1904 thirty-two autopsies were performed; twenty-eight are included in the preceding report, one other was upon an experimental "locoed" sheep at White Sulphur, Montana; three autopsies upon cattle have been discarded as they were performed hurriedly and were unsatisfactory. In the twenty-nine autopsies on sheep the principal diseases and parasites observed were:

TABLE X

	Times
Thysanosoma actinioides, Total	29
Thysanosoma with peribiliary hepatitis	14
Thysanosoma with an abscess or infarction of liver	2
Stomach worms (Ostertagia marshalli)	8
Other intestinal worms	5
Lung worms	3
Oestrus ovis larvae	15
Sarcocystis tenella	15
Pneumonia, Total	18
Pneumonia, with lung worms	1
Pneumonia, with bronchiectatic abscesses, or cysts	4
Pneumonia, with oestrus ovis	15
Pneumonia, of unknown origin	3
Pneumonia, with pleurisy or empyema	2
Acute enteritis	1
Cysticercus tenuicollis in peritoneal cavity	8
Cysticercus in pericardial cavity	1
Abscess, supposedly around cysticercus, total	5
Abscess, on epicardial surface	2
Abscess, on liver	1
Abscess, in peritoneal cavity	2
Hair balls in stomach	2
Renal calculi	2
Extradural abscess	1
Necrosis in lymph gland	1
Inflammatory nodule in kidney	1
Irregular incisor teeth*	14
Emaciation	16

* No note upon the teeth was made in other autopsies.

The *Thysanosoma actinioides*, or *Taenia fimbriata*, or "fringed tapeworm" has attracted attention in this country chiefly from Curtice, (4th and 5th Annual Reports, Bureau of Animal Industry, 1887–1888; pp. 167,–186; also "The Animal Parasites of Sheep," Washington, 1890; also *Vet.*

Record 1, p. 59). He found that the smallest worms appeared in lambs of about two months age, and occurred in sheep of all ages, and at all seasons except possibly during the winter months. He was unable to remove the parasite by treatment. He concluded that disease resulting from infection with this parasite was commonly called "loco" disease, and he was sceptical regarding the existence of true locoweed poisoning in sheep. He estimated that the losses from death of sheep and depreciation due to this parasite, were enormous, lambs and yearlings suffering chiefly. Practically all Western flocks seemed to be infected but it seemed to be especially common among the descendents of the Mexican or Spanish sheep with which the larger ranches were originally stocked. In all, he found 89 per cent of Western sheep infected.

He saw the worms in the duodenum and bile ducts, the ducts being so tightly distended with them at times that the worms could not be extracted except in pieces. He also saw the worms in the pancreatic ducts. Thickened and dilated ducts were found occasionally with no worms in them. The chief features of the disease produced by the worms were those of progressing malnutrition, or cachexia, with occasional excess of fluid in the serous cavities. In fatal cases death usually was due to starvation, exposure, or intercurrent disease.

My findings corroborate those of Curtice in certain respects and in addition I have been able to demonstrate a serious lesion of the liver, with the appearance of a necrotic, organizing area in the liver, resembling an infarction; while in one case (No. 4), there was a fungating liver abscess in connection with an extensive hemorrhagic subdiaphragmatic abscess. In a number of autopsies the microscopic studies demonstrated the presence of a process of fibrosis, more or less advanced, proceeding from around the thickened ducts and extending out into the liver substance.

In other words, these cases establish a new form of chronic inflammation of the liver, a form distinct from liver fluke disease on the one hand and from the inflammation resulting from gall stone obstruction on the other, for here the tapeworm, *Thysanosoma*, is responsible for the disease.

It may also be remarked that vacuolar changes were present in the pancreatic cells in a case where the pancreatic duct was filled with the tape worm. From the nature of my work it was impossible to determine the clinical course of the disease, but it seemed clear that heavy infections were frequently associated with malnutrition or cachexia.*

* A description of the microscopic changes in the liver together with a demonstration of sections was given by me in an article read before the American Association of Pathologists and Bacteriologists at Philadelphia in April, 1912.

Oestrus ovis infection. Aside from the microscopic studies of the nasal mucous membranes and cervical lymph glands, detailed in the autopsies at the end of Section C, my studies emphasize only two points with regard to *Oestrus ovis* infection: first, that this parasite is a source of danger to Western sheep; second, that the severity of the symptoms produced by the parasite depends most intimately upon the general condition of the animal, and upon the amount of nutritious food which it receives.

It is of interest to observe that the *Sarcocystis tenella* was present in practically every case in which the microscopic examination was made except in the case of lambs only 3 or 4 months old. It is, however, not generally regarded as a dangerous infectious agent, although according to J. Fiebiger, (*Die tierischen Parasiten der Haus-und-Nutztiere*; 1912, p. 113–119) during one year 1½ per cent of sheep at Budapest were condemned as unfit for food on account of infection with this parasite.

No special remarks are required concerning the lung and stomach worms, for parasites of this type are known the world over. It is to be noted however, that this report together with the recent work from the Bureau of Animal Industry shows that the semi-arid condition of the general grazing grounds in the West is no protection against the spread of several dangerous parasites, when the bed grounds, watering places, etc., are allowed to become polluted, and to remain so.

E. REVIEW OF RECENT PUBLICATIONS DEALING WITH LOCOWEED DISEASE.

The office of the Poisonous Plant Investigations in the Bureau of Plant Industry continued the study of locoweed disease, after the conclusions which I drew from the field work of 1903 and 1904 had been submitted. A double-headed campaign was launched, in which Dr. Albert C. Crawford (*loc. cit.*) conducted investigations designed to test the poisonous action of the locoweed under laboratory conditions and to ascertain the nature of the poisons obtained, while Dr. C. Dwight Marsh (*loc. cit.*) carried out experimental studies of the loco problem in the field.

After a scholarly review of the literature, Crawford details his own elaborate experiments, which led him to conclude that the symptoms of loco poisoning can be reproduced in rabbits by feeding them extracts of certain loco plants; that the symptoms in the rabbits which he studied were due to the barium in the locoweed extract; that there may be other poisonous principles in locoweeds from other regions, and that locoweed grown on some soils contains no barium and is not active.

As Dr. Crawford did not test the locoweed grown in the region where

my experiments were conducted, it cannot be determined, except by a special study, whether he would have placed these particular locoweeds in the barium-containing, actively poisonous group, or in his inactive group free from barium. But this much is certain; the sheep which ate this locoweed freely for the greater part of the fifty-three days of the experiment presented neither the symptoms, nor anatomical changes which Crawford gives as characteristic of barium poisoning. A recent publication by Alsberg and Black weakens the force of Crawford's conclusions. These writers, (Bureau of Plant Industry, 1912, Bull. 246) as the result of experiments and other considerations which they record, are led to the conviction that the toxicity of locoweeds in laboratory experiments is not due to barium, and Marsh also (Bull. 246) concludes from studies in the field that typical loco poisoning is not produced by barium feeding alone. Up to the present no further laboratory studies have been published, and it now looks as if Crawford's view as to barium cannot be maintained, but that his experiments at least suggest that some locoweeds contain a poison of unknown nature which other locoweeds do not contain.

The second division of the attack upon the loco problem was under the direction of Dr. Marsh who conducted feeding experiments upon a larger and more thorough scale than had ever before been attempted. For three seasons, 1905, 1906, and 1907, horses and cattle were fed upon locoweed in three camps established in Colorado and Nebraska. The animals were observed during life, autopsies were performed on many of them, and many other locoed animals, horses, cattle, sheep, and goats were examined. Accounts of the experiments and of the results obtained appear in several bulletins from the Department of Agriculture, and in reports from the Agricultural Experimental Stations of Colorado and Nebraska which actively coöperated in Marsh's work. From these accounts it is clear that Marsh believes that he has solved the loco problem, that he has proved that the locoweed is poisonous, and that he has established symptoms and anatomical changes which are together equally characteristic of locoweed intoxication. It is, however, difficult for a medical reader studying Marsh's reports to follow him to his conclusions, for the data which he prints in his technical report (Bull. 112), and elsewhere, do not always make it logically necessary for the reader to come to the same conclusions that Marsh reached. This is noticeable between pp. 47 and 72 in his review of cases, where it cannot be seen by the reader that Marsh has always excluded other possible diagnoses with sufficient fulness to justify his conclusions that the animals described owed their maladies to the locoweed. This deficiency may be corrected when he publishes in full his anatomic, microscopic, and bacteriologic stud-

ies, which references in Bulletin 112 allow us to expect. It is, however, clear that Marsh's animals on locoweed diet became ill and died, while controls, not eating locoweed remained healthy. The following analysis of Marsh's publications represents an attempt to construct the clearest possible medical description of Marsh's animals, and incidentally indicates the variations which he mentions. Marsh, (Bureau Animal Industry, Bull. 112; 1909, p. 114) claims that "animals eating (the loco plants) succumb sooner or later to their poisonous action." He modifies this statement elsewhere; thus, (Farmer's Bull. 380, p. 10):

> During the spring months, before the grass starts, where the white locoweed is abundant practically all animals eat more or less of it. As the grass becomes more abundant, many of these leave the locoweeds and devote themselves entirely to grass. These animals as a rule do not seem to be injured by the habit. Others . . . . continue to eat the locoweed even where there is an abundance of other feed. Whether an animal will become locoed or not is then simply a matter dependent upon the individual. Some cattle and horses will eat locoweeds for a part of the year, for a period of years and suffer no harm. Others . . . . eat this plant almost exclusively, and these will die within a few months, or, in some cases, even within a few weeks.

The same idea occurs also in Bulletin 112 (Case No. 10., etc.)

The symptoms were essentially like those popularly described, a staggering, stiff, and uncertain gait, the hind legs being dragged frequently; a general disturbance of the nervous system which leads in some cases to an apparent partial paralysis of the limbs and to a very distinct lack of muscular coördination. Anaesthesia of the skin may be pronounced.

> "The animals eating loco eat more and more of it, although they do not in all cases acquire a passionate love for the weed, and sooner or later lose flesh, and die of starvation." . . . . "The first pronounced symptom (Bull. 246, p. 34) is in the gait, which is stiff with more or less evidence of partial paralysis. There is a lack of muscular coördination, which produces 'high stepping,' rearing, jumping and stumbling." In drinking, the mouth moves in a peculiar way, somewhat as in eating. "The animal is either dull and dejected or in constant motion . . . . It gradually loses flesh, its coat becomes rough, its eyes staring, it becomes profoundly anemic, and eventually it dies of starvation."

Abortion is common among locoed cows. The temperature is usually normal, but varies from subnormal to 108°F. Marsh's colleagues, Peters and Sturdevant, from the Nebraska Agricultural Experiment Station (21st Annual Report, 1908) add to these symptoms, that the horses experimented with showed distinct irregular swellings more or less bilaterally symmetrical, which appeared early on the cheeks and side of the lower jaw as well as "on the place behind the lower lip." Lymphatic enlargement in the inter-

maxillary space also appeared early. Marsh found (p. 92) that "during the early period of loco feeding there were no symptoms of poisoning. Horses and cattle will eat quite freely of the weed for a considerable period with no apparent ill effects and may even gain considerably in flesh." Marsh frequently speaks of malnutrition among his animals, and of their starving to death, but it is only very recently (Farmers Bulletin 536, issued May 1, 1913), that he has begun to come around to the view expressed in my reports of 1903 and 1905 that underfeeding is one of the main causes of the loss of Western live stock.

Great individual differences were found to exist among animals in regard to susceptibility to the loco poison; in general, the better bred animals succumbed more quickly. Horses were the principal animals attacked in regions where the *Astragalus mollissimus* prevailed. This was found much more toxic than the *Aragalus lamberti* which did more damage to cattle and sheep than to horses.

In most of his experimental animals the symptoms were of sudden onset. The weed was eaten by the animal with no evidence of injury until a relatively short time before death, when symptoms developed rapidly. The interval from the time the animal began to eat locoweed until its death varied from two months and eight days to six months and nine days; with cattle the average interval was about five months, with horses rather less. If the animal ate only moderate amounts of loco, a fatal outcome was indefinitely delayed. Cases of "acute" locoism in lambs were met with in which death resulted in two or three weeks from the first eating of the locoweed. Age was not a factor in the disease, old as well as young animals becoming locoed.

Marsh states (p. 114), that there were certain quite definite anatomical changes found at autopsy.

> The animals were strongly anemic. This anemia was indicated not only by paleness of flesh and actual loss of blood, but by serous deposits in various parts of the body. The blood was found to be poor in hemoglobin and commonly rather rich in leukocytes.

Elsewhere (p. 95) he says that the anemia

> is indicated not only by the emaciation and paleness of the flesh, but by the excess of serous fluids of the body and by the deposits of organized serum in various parts of the body. This is more especially marked at the base of the ventricle of the heart.

Elsewhere (Farmer's Bull. 380, p. 12) Marsh states:

The postmortem examinations of locoed animals do not in all cases show clearly marked evidence of the progress of the disease. Since in all cases of fatal poisoning the locoed animals die of starvation they are profoundly anemic, as would be expected, and, as a result of this anemia, accumulations of coagulated serum in gelatinous form are found in various parts of the body. These accumulations are particularly prominent about the heart. There is also an accumulation of coagulated serum in the cavity of the spinal column. This is almost always present in cases where the loco poisoning has become a chronic condition.

This remarkable condition in the spinal canal is described as follows by Marsh in the section of his main work devoted to the antomical changes (p. 97–98):

The central nervous system is generally in a hyperemic or congested condition. In a few cases clots were found in the lateral ventricles of the brain. We have never, however, found clots in the fourth ventricle . . . . The serous exudate in the epidural space is especially abundant, and is more or less organized. Commonly it is particularly abundant about the points of exit of the spinal nerves. This condition is rarely absent in chronic locoes. . . . . In some cases this coagulated serum is especially abundant in the lumbar region . . . .

Later (p. 114) he states that the fluid of the epidural space of the spinal canal is rather unusually abundant, and commonly more or less organized, "so that the spinal canal frequently seems to be filled with a jelly like substance." Peters and Sturdevant, Marsh's colleagues, describe as follows the condition as it was met with in a seventeen months old horse which died under loco treatment (21st Annual Report; Agricultural Experimental Station of Nebraska, 1908). Between the dura mater and the periosteum of the vertebrae enclosing the neural canal all along the spinal cord there was a cherry red transparent organized exudate in great abundance. In another horse the exudate varied from a buff color in the lumbar region to a very dark red in the cervical region. The color of the exudate was due to numerous tiny blood vessels running through in all directions. The exudate "was not adherent to either periosteum or dura but clung to the spinal nerves at their origin, since it ran through and filled the opening between the anterior and posterior nerve roots in each case and was thus held in place by these."

Marsh also autopsied five lambs which died of acute loco disease lasting only two or three weeks (p. 71). All were in good flesh; "all had clots in the lateral ventricles. All had serous coagulum in the spinal canal, and all had congested walls of the fourth stomach. This would seem to confirm our opinion that these lesions are characteristic of the locoed condition, but that in chronic cases they may be more or less masked." There is some

contradiction between this and his reiterated statements that these lesions, especially the spinal canal lesions, are peculiarly characteristic of *chronic*, not of *acute*, loco disease. Moreover, as these lambs were affected for only two or three weeks, the anemia alone would hardly have progressed with such rapidity as to cause the serous effusions, in the absence of some more direct cause. From these accounts it appears that this peculiar 'coagulum' was sometimes outside the dura, 'epidural,' at other times in the cavity of the spinal column.

Marsh found also changes in the stomach at autopsy on locoed animals. (p. 114) "A diseased condition of the stomach was a common accompaniment of the locoed condition, this being marked in cattle by ulcers in the fourth stomach." In another place, (p. 97), he says:

> In acute cases the (stomach) walls are very much inflamed. In chronic cases ulcers are commonly present. The ulcers are not so common in the stomach of horses, but are almost invariably present in the fourth stomachs of cattle. In sheep one is apt to find inflamed walls rather than ulcers. In these ulcers a microscopic examination shows that the mucous membrane is entirely destroyed. Sometimes other parts of the alimentary canal may be inflamed or have small ulcers but this is not a usual condition.

In another place (Bull. 246, p. 34) he states, that, as the result of loco feeding, ulcers are found in the stomachs of horses and in the fourth stomachs of cattle and sheep. In addition Marsh found that the hemolymph glands were unduly prominent and very numerous, and ovarian disease was common.

The picture was not uniform in all of Marsh's experimental animals. Two horses developed acute glanders (p. 461). Others, according to Glover, Marsh's colleague (Colorado Agricultural Experiment Station, 18th Annual Report, p. 52), showed unmistakable symptoms of starvation, and on careful autopsy, revealed no characteristic lesion.

Marsh lays great emphasis upon the anemia observed in locoed animals. He found no blood parasites upon examination (p. 92). He found it impossible, however, on account of other duties to secure any very large number of blood determinations. Some counts were made during the second and third summers. The normal number of red corpuscles for healthy cattle was found to be something over 8,000,000. The count was high, as the experiment camp was at an altitude of 5,000 feet above the sea. The hemoglobin (Tallquist), averaged between 90 and 95 per cent. Very severely locoed animals in the last stages of the disease, examined in 1906 gave an average of over 5,000,000 corpuscles, with hemoglobin averaging 70 per cent, while convalescents and those less severely locoed, examined in 1907

averaged over 7,000,000 red corpuscles, with hemoglobin averaging 85 per cent. The hemoglobin estimations on ten healthy sheep gave an average of 87 per cent; on fourteen locoes the average was 78 per cent.

Now these figures given by Marsh show that in none of his cases was the hemoglobin reduced to an extreme degree even in the worst cases recorded, while in the sheep it was relatively insignificant. Although the red corpuscles in some of the severe cases were reduced nearly one-half, it seems peculiar, with the high hemoglobin count, that the anemia alone should be severe enough to explain the remarkable and characteristic serous collections in the heart, spinal canal, and elsewhere.

With regard to the white blood corpuscles Marsh states, (p. 96), that "An average of twelve locoes in 1907 showed 3,735 white corpuscles." This is the only observation which he records upon the white corpuscles, and it cannot be reconciled with his conclusion (p. 114) that the blood was "commonly rather rich in leukocytes." According to Marek (*Klin. Diagnostik der inneren Krankheiten der Haustiere*, pp. 869–887), the white corpuscles of cattle vary between 7,000 and 10,000 during health, so that Marsh's average of 3,735 actually shows a decided reduction and not an increase. According to Marek the red corpuscles of cattle vary in health between 5,000,000 and 7,000,000 per 1 cc., the hemoglobin averaging 65 per cent by the Gowers, or v.Fleischl methods of estimation, which would give a somewhat higher normal reading by the Tallquist method employed by Marsh. In sheep, according to Marek, the normal red count runs from 8,000,000 to 11,000,000; hemoglobin about 55 per cent. Comparing these standards of healthy livestock with blood determinations recorded by Marsh, it is seen Marsh records no cases of severe anemia, and it seems improbable that what he calls "serous accumulations" were the result of anemia.

Marsh studied loco disease in sheep during 1906 and 1907. During 1906, sixty-three yearling bucks and six lambs were studied. All were supposed to be locoed at the time they were received, and some were very weak and in bad general condition (p. 66). Soon after the first lot of bucks were received at the experimental camp, they were fed upon hay mixed with locoweed (*Aragallus lamberti*). *Only twelve of these "locoed" animals would eat the weed at all and even they would only nibble at it. The others did not eat the plant at all, although they were locoed sheep in bad general condition—presumably advanced locoes* (italics are mine). As the season wore on all of them ate more or less locoweed, just how much could not be determined. There were some which ate nothing but locoweed. It is to be observed that these sheep were "*locoed*" when Marsh received them but

they did not form the *locoweed habit* until some time later. Thirty-three of the sixty-five sheep were examined at autopsy, disclosing 23 cases of sheep fly disease, more or less severe; 23 cases of infection with *Thysanosoma actinioides*; a serous coagulum in the epidural space of the spinal canal eighteen times; inflammation of the fourth stomach thirteen times; blood clots in the lateral ventricles nine times, etc. Upon these findings, and regardless of the fact that his "locoed" animals did not eat locoweed, until forced to it, Marsh concluded (p. 70) that "The principal difficulty with most of the animals in 1906 was the loco poison, with the effects complicated by parasites." He examined more sheep the next year, however, and, though he gives no details of the second group of sheep, he states; "the chief trouble with most of the sheep in 1907 was caused by the parasites, and that the loco had little if anything to do with their condition." He then goes on to make the significant statement:

> The general appearance of the bands of sheep in 1906 and 1907 was the same, and not only the author, but experienced sheepmen, declared that both bands were locoed. In the majority of cases it was only by postmortem examinations that the diagnosis could be confirmed.

It is perfectly obvious that this statement by Marsh at once knocks the props from under the carefully constructed and elaborate group of symptoms which he gives as characteristic of loco disease. At least in the case of sheep these symptoms are not of differential value, and it is certainly impossible to detect the slightest difference between the photographs of Marsh's locoed sheep, and photographs taken by Professor Chesnut of the sheep studied by me.

Marsh tries to redeem his position by adding, (p. 70):

> If the habits of the sheep are observed there is a marked difference (between locoed sheep and those suffering from parasitic disease). The sheep affected with *Oestrus ovis*, except when they are in very bad condition, keep together like normal animals, and show a preference for good food, although they may at times eat loco. The locoed sheep on the other hand, are more erratic, and develop a solitary habit to a greater or less extent. They show, too, a marked fondness for the locoweed. At the same time, when one is dealing with a considerable number of sheep, it is a matter of much difficulty to separate the locoed animals from those affected with the grub in the head.

Marsh does not even consider the difficulties of differentiating loco from any other prevailing parasitic diseases of sheep except the sheep fly disease. Moreover, the force of his argument is lost when it is observed that his own typical locoed sheep of 1906 ate the locoweed either not at all or only sparingly (p. 67–68), and when it is added that the sheep studied by

me, which ate abundantly of locoweed, were not erratic and developed a solitary habit only as starvation and parasitic disease brought them nearer to death. In other words the clinical symptoms given by Marsh do not differentiate locoed sheep from other ill sheep not locoed. In another place, (p. 92) Marsh himself acknowledges that this is the case, for he says, "after some experience we could, by postmortem examinations, distinguish locoes readily, but it is very difficult before death to tell a locoed sheep from one suffering from grub in the head."

If we compare Marsh's findings with the findings in the typically locoed sheep studied by me, it becomes perfectly clear, that while the symptoms were often strikingly similar, not one of my typical locoes presented the anatomical changes which Marsh found to be characteristic of loco disease in horses, sheep and cattle. In other words, sheep suffering severely from what is everywhere called "loco disease" in Montana, differ in important essentials from animals suffering severely from what is called "loco disease" in Colorado and Nebraska. That is to say, Marsh's work serves to emphasize the truth of my conclusion that "loco disease" is not a clinical entity, but is a term used by Western raisers of live stock to designate several widely different forms of stock disease.

The exact and final diagnosis of locoweed appears then to depend chiefly (at least in sheep), upon finding a peculiar coagulum in the epidural space of the spinal canal, or within the spinal canal. Such a lesion in the central nervous system is unusual, except in diseases such as those referred to below. That this material is a serous effusion, as Marsh describes it, is incompatible with its occasionally being found in a state of organization, as described by Marsh (p. 95, p. 97), and by Peters and Sturdevant. The description suggests that the material was an inflammatory exudate. That such an accumulation should occupy, not only the spinal canal, but a position between the dura and the periosteum, is peculiar. That an effusion of such a nature in such a situation, and one capable of undergoing organization should result from eating a poisonous plant is little less than amazing. And yet this lesion is, after all, the most important feature of Marsh's description. It is easy enough to find symptoms like those of his locoes in several other diseases described in veterinary text books; while anatomically the catarrhal condition of the stomach and even the ulcers are not distinctive of loco poisoning, and the other lesions are relatively unimportant. This makes a detailed description of the lesions in the central nervous system essential to the establishment of Marsh's disease. Such a description including microscopic and parasitologic studies has not been furnished.

In summing up Marsh's work, it seems that he has called attention to a disease which develops in some of the animals which eat locoweed. Not all loco eaters get it, but chiefly those which eat locoweed almost exclusively. There are great individual differences in susceptibility among animals to the poisoning. Peculiar nervous and mental symptoms with progressive weakness, paresis, or partial paralysis of the hind quarters mark the progress of the disease, together with an increasing tendency to eat locoweed. The disease develops suddenly two or three months after beginning to eat the weed. The animals die of starvation, and at autopsy show serous effusions; a peculiar exudate in the vertebral canal, either outside the dura or around the spinal cord, with congestion of the vessels of the brain and occasionally hemorrhages into the lateral ventricles. There is congestion, or ulceration, or both, in the stomach of horses, and in the fourth stomach of cattle or sheep. The anatomical condition may vary more or less in regard to the central nervous system and the stomach.

Several diseases have been described which somewhat resemble Marsh's "loco disease." Pica, or licking disease (Nagesucht; Lecksucht), is interesting, as it also bears a relation to the soil conditions, and to certain hays in the diet. This disease, which, according to Hutyra and Marek (*Spezielle Pathologie und Therapie der Haustiere*, 3rd edition, vol. 1, p. 960), affects cattle almost exclusively, when confined to stables for long periods, is produced by certain kinds of hay, depending upon whether the hay was cut before or after the bloom, etc. Hay from certain localities only will produce the disease, and there is apparently an obscure relationship between the disease and the poverty in soda and lime salts, or excess of potash salts in the hay. The symptoms of the disease are like locoism, and the gastric mucosa is inflamed but there is no description of any spinal exudate.

Catarrh of the fourth stomach, chiefly in cattle, would readily pass for loco disease except that no special changes have been described in the central nervous system. It is interesting to note that this disease may follow various kinds of improper food, and that highly nitrogenous foods like vetches may produce it.

Of more interest are the descriptions of meningo-encephalitis, for here the description both of symptoms and of anatomical changes agree rather better with Marsh's account of loco disease. Law (*Veterinary Medicine*, vol. III, 3rd ed. p. 95–6) makes the following statement:

> Among the most common causes of encephalitis in horses is an injudicious dietary. Overfeeding with grain, but especially with grain and seeds that are rich in albuminoids, deserves the first mention. The various leguminous seeds, peas, beans, tares, vetches, and the ripened leguminous fodders, clover, alfalfa and sainfoin, are espe-

cially to be incriminated. These are usually most dangerous when in the stage of advanced ripening and yet not fully matured, evidently indicating the development of narcotic poison at this stage. Such poisons are found habitually in certain species, like the chick vêtch (*Vicia cicera*), which produces paralysis if fed to the extent of more than one-twelfth part of the ration. . . . . With sound judgment and in well balanced rations, all such agents can be fed to advantage; it is only when fed exclusively or to excess as the heavy ration that they are to be feared.

The symptoms of this disease are largely those of Marsh's loco disease, though the disease runs a fatal course more rapidly than appears to be usual in Marsh's cases. There is a fairly close resemblance between the anatomical findings so far as can be judged by reading the accounts of the two diseases.

Law does not make the distinction very clear to the reader between meningo-encephalitis and the epizootic cerebro-spinal meningitis of horses. The latter disease is known in Idaho (Law), and both symptoms and anatomic changes are largely those of the loco disease of Marsh.

Hutyra and Marek (vol. 2, p. 624, &c.; and p. 634–645), differ somewhat from Law in their description of the two last described diseases, the chief difference being that they lay little stress upon the food, and attribute each disease to a specific bacterium. In their discussion of the differential diagnosis (p. 632) they outline several diseases which would undoubtedly pass for loco on the ranches. Until Marsh publishes his microscopic and bacteriological studies it will be impossible to decide whether Marsh's loco disease is identical with meningo-encephalitis or with enzootic cerebro-spinal meningitis, but in the meantime it seems rather more probable that Marsh's disease is allied to meningo-encephalitis.

F. THE LOCO PROBLEM.

Crawford's review of the literature sets forth strikingly the state of interminable confusion in which the loco problem has been involved since the very beginning, a state due to the vagueness of the definition of loco disease, and to the discrepancies in the description of symptoms, in the statements of fact, and in the results of experiment. Crawford himself decided that a poison can be extracted from some locoweeds but not from others. This fact may yet be established in spite of Alsberg's contention that the poison is not barium, a contention supported by Marsh. My studies failed to reveal any indications that the animals were poisoned by locoweed, while Marsh is fully satisfied that he has established the poisonous activity of locoweed beyond all doubt. Even Marsh found that eating locoweed does not always produce loco disease, and he lays emphasis upon

the persistent, and almost exclusive use of the plant as more or less necessary in order to produce poisoning. There seem to be exceptions even to this rule, due to great individual differences among animals in their toleration for the plant. Many animals actually gain weight on a loco diet.

At the present the work of Crawford, Marsh and myself seems to justify opinions upon several aspects of the loco problem, provided we temporarily concede that Marsh's disease results from the use of the locoweed and is not due to bacteria or parasites.

1. Some locoweeds, including *Aragallus lamberti* and *Astragalus mollissimus*, may exert a deleterious action upon live stock. Apparently not all locoweeds are equally injurious. That the deleterious action is due to a definite poison in the weed, as claimed by Marsh does not seem to be established.

2. There are wide individual variations in the results obtained from feeding live stock upon locoweed. Some animals die; others may actually gain in weight for a certain length of time. Animals may eat the weed as part of their ration for years with no bad results.

3. It requires a large amount of locoweed to produce symptoms. The proportion of locoweed in the diet must be large; in fact in locoism the animals seem to feed chiefly on the weed. Sheep and lambs feeding on the weed as freely as they wanted it were not locoed after eating the weed *A. spicatus* for over forty days, while the closely allied species *A. lamberti* apparently produced locoism in Marsh's cattle and horses after two to five months of feeding.

4. It is an easy matter to make the animals eat locoweed. It is only necessary to reduce the amount of available food, or of available fresh green food, for a short time in order to start sheep eating the weed. They will eat it readily—more readily than other grasses, apparently—but not exclusively, as a rule.

5. The disease described by Marsh as "loco disease" bears a certain resemblance to meningo-encephalitis.

6. There are several other diseases of live stock on the Western ranches which are generally regarded as loco disease.

7. Underfeeding or improper feeding appears to be a very important factor in causing losses among the live stock. Entire flocks of sheep may be underfed if the range is overstocked; or if several flocks in quick succession pass over the same range; or if the season is a poor one for the growth of range grass. The younger and weaker members of a band of sheep will always suffer most from underfeeding, as they cannot keep in the front ranks where the best food is, and they should be particularly cared for, or

even removed, while they are still in good condition, and fed up in a group by themselves.

8. Parasitic diseases, passing as "loco disease" are widely spread among the sheep of Montana, and probably throughout the West. The parasites which have come to light during the loco studies are: 1st, the "fringed tapeworm" (*Thysanosoma actinioides*): 2nd, a wire worm of the stomach (*Ostertagia marshalli*): 3rd, a lung worm; 4th, in sheep which are in poor condition the ubiquitous sheep fly disease may produce serious or fatal illness. The other parasites observed such as the *Sarcocystis tenella* are of less serious moment.

9. The hygenic conditions on the ranches, around the bedding grounds for the sheep, and at the watering places, especially in the latter situation seem peculiarly favorable for the wide dissemination of the parasitic diseases above mentioned. It does not seem at all probable that the loco studies have brought to light all of the diseases masquerading as "loco disease."

The unexpected development of the loco work pointing to underfeeding and parasitic infections leads to problems of immediate importance, so great as to overshadow the original loco problem. It would be very interesting to continue to experiment with the loco plant, but the call of the hour is to combat the losses of live stock by tackling the feeding problem, and by making a thorough medical survey under the direction of trained parasitologists to determine the nature and extent of prevailing parasitic diseases, and to inaugurate measures to combat them. Further investigations of the locoweed at the present time will serve only to postpone the day of relief for the stock raisers. Not until the two problems of underfeeding and infection have been attacked successfully can we hope for a satisfactory settlement of the loco problem.

Even in the case of Marsh's disease it will be necessary to do much work before Marsh's recommendations can be justified. He advises that the locoweed be exterminated by combined action of the individual rancher, the state and the nation. The enormous cost of such an undertaking calls for the most careful work to justify it. It will not be until it has been proved that Marsh's disease itself is not dependent upon some microörganism; until it has been clearly established that it does not exist outside of the locoweed belt, and that only animals eating the weed are victims of the disease; and until the food value of the weed, and its value as part of a ration have been learned—not until these matters are settled can Marsh's recommendations be advocated. If Law is correct in the quotation given above, and if the locoweed is like its relatives in the plant kingdom, it may

well be found that the locoweed is a good food if used in moderation and in association with other foods and at certain seasons of the year. Both my animals and Marsh's gained in weight upon a locoweed diet. Disaster followed only the prolonged and almost exclusive use of the weed by his animals. On the other hand, recent work in the Bureau of Animal Industry lends support to my view that the parasitic diseases must be attacked if the Western live stock industry is to be properly conserved. Recently Hall (27th Annual Report Bureau Animal Industry, 1912, p. 419), referring to the parasites of Western sheep, says, "Even relatively light infections are apparently sufficient to cause the death of an animal in adverse weather conditions or during periods when food is scarce." Moreover, evidence is accumulating to support the opinion expressed by Curtice a generation ago, to the effect that the "fringed tape-worm" does more harm to Western sheep than any other internal parasite, (Ransom: Report Bureau Animal Industry, 1911, p. 60). In view of the prevalence of the parasitic diseases when they were looked for, it seems not unreasonable to expect that an attack upon these diseases combined with an attack upon the feeding problem will clear up the majority of the "loco diseases." It seems even more probable that such a campaign will most surely and speedily diminish the huge losses among the Western live stock.

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